Impact of relevance instructions and elaborative interrogation on the processing of expository texts: Evidence from eye movements

El impacto de las instrucciones de relevancia y de la interrogación elaborativa en el procesamiento de textos expositivos: Evidencias desde los movimientos oculares

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ABSTRACT

Comprehension of instructional and expository texts is an important area of research in learning contexts. Throughout the last decades, literature related to educational and experimental psychology has been composed by a large number of studies focused on the improvement and development of the learning processes of the students. The main objective of the studies of the present doctoral dissertation is to apply the eye tracking methodology to study the effect of relevant instructions and elaborative interrogation on the processing strategies and reading comprehension of expository texts. Several innovations are proposed, such as the use of the paragraph as the main unit of analysis in the text, the application of a detailed analysis of the eye movement patterns in text processing, and the combination of online measures as the eye tracking methodology, with offline measures as the quality of the recall from different expository texts. In addition, some of the studies of this dissertation use more robust, efficient and modern statistical models than traditional analysis of variance, such as linear mixed effects models.

The main results observed from the empirical studies of this dissertation indicate that providing specific relevance instructions, as well as inserted “why” questions, or the combination of both, elicit readers to use a strategic and selective processing during the reading tasks. This selective processing is reflected in the online eye movement measures, showing higher firstpass and rereading times for question-relevant information compared to irrelevant, and also in the offline measures of the quality of the recall from the oral summaries produced after reading, showing higher recall rates for question-relevant information compared to irrelevant.

Based on the results found in the studies, potential educational implications are inferred, that may be relevant for learning environments. As it has been shown, the implementation and application of specific relevance instructions and inserted “why” questions, can offer consistent benefits to learning and understanding when facing students to reading tasks related to expository texts, promoting and facilitating more efficient, strategic and selective reading processing, which can finally lead to an improved understanding and learning from texts.

RESUMEN

La comprensión de textos instruccionales y expositivos ha sido y es un área nuclear y recurrente en contextos de aprendizaje. A lo largo de las últimas décadas, la literatura relativa a la psicología educativa y experimental se ha nutrido de una importante cantidad de estudios centrados en la mejora y el desarrollo de los procesos de aprendizaje de los estudiantes. El objetivo principal de los distintos estudios de la presente tesis doctoral es el de aplicar la metodología de los movimientos oculares al estudio del efecto de las instrucciones de relevancia y de preguntas adjuntas sobre las estrategias de procesamiento y la comprensión lectora de textos expositivos. Se plantean una serie de innovaciones, tales como el emplear el párrafo como como la principal unidad de análisis en el texto, la aplicación de un análisis pormenorizado de los patrones de movimientos oculares en el procesamiento de los textos, así como la combinación de medidas online, como la metodología de movimientos oculares, con medidas offline como la calidad del recuerdo para la lectura de distintos textos expositivos. Adicionalmente, en algunos de los estudios de esta tesis se emplean modelos estadísticos más robustos, eficientes y modernos que los análisis de varianza tradicionales, como son los modelos lineales de efectos mixtos.

Los principales resultados que se desprenden de los estudios empíricos de esta tesis indican que proporcionar instrucciones específicas de relevancia, así como preguntas adjuntas de tipo "por qué", o la combinación de ambas, induce en los lectores un procesamiento estratégico y selectivo en las tareas de lectura que llevan a cabo. Este procesamiento selectivo se refleja tanto en las medidas online de movimientos oculares, mostrando tiempos de lectura y relectura superiores para la información relevante frente a la irrelevante, como en las medidas offline de calidad del recuerdo y de los resúmenes

orales producidos después de leer, en las que se muestran tasas de recuerdo superiores para la información relevante frente a la irrelevante.

De los resultados encontrados en estos estudios, se desprenden potenciales implicaciones educativas que pueden ser relevantes en entornos de aprendizaje. Tal y como se ha demostrado, la implementación y aplicación de instrucciones específicas de relevancia y de preguntas adjuntas de tipo por qué, puede ofrecer beneficios consistentes en el aprendizaje y la comprensión a la hora de enfrentar a los estudiantes a tareas de lectura y de análisis de textos expositivos, promoviendo y facilitando estilos de procesamiento lector más eficientes, estratégicos y selectivos, que desemboquen al mismo tiempo en una comprensión y un aprendizaje mejorados de los textos.

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1. INTRODUCCIÓN TEÓRICA

1.1. Marco histórico reciente sobre instrucciones y preguntas adjuntas

A lo largo de la presente introducción teórica se tratará de ofrecer un marco general donde situar los principales modelos y los estudios más recientes sobre los efectos de las instrucciones y de las preguntas adjuntas en los procesos de lectura y de comprensión ante textos expositivos.

La comprensión de textos instruccionales y expositivos ha sido y es un área nuclear y recurrente en contextos de aprendizaje. A lo largo de las últimas décadas, la literatura relativa a la psicología educativa y experimental se ha nutrido de una importante cantidad de estudios centrados en la mejora y el desarrollo de los procesos de aprendizaje de los estudiantes (e.g. Armbruster, 1984; Armbruster, Anderson, & Ostertag, 1987; Faw & Waller, 1976; Hamaker, 1986; Hamilton, 1985; Kantor, Anderson & Armbruster, 1983; Peeck, 1970).

Una de las primeras aproximaciones experimentales realizadas en el campo de los textos expositivos es la del llamado "efecto de la perspectiva" (*reading perpective*). Bajo esta aproximación se asume la idea de que, poseer una perspectiva específica en mente cuando se está procesando un texto expositivo, resulta una forma eficiente de facilitar un procesamiento selectivo durante la lectura. En este sentido, y desde la década de los 80 se ha dedicado una considerable cantidad de investigación para comprobar los posibles efectos positivos que esta hipotética perspectiva podría generar en la conducta lectora y en la subsiguiente representación mental del texto (e.g., Anderson, 1982; Anderson & Pichert, 1978; Baillet & Keenan, 1986; Goetz, Schallert, Reynolds, & Radin, 1983; Hyönä, Lorch, & Kaakinen, 2002; Kaakinen, Hyönä, & Keenan, 2001, 2002, 2003; Kaakinen & Hyönä, 2005, 2007, 2008, 2011; Kardash, Royer, & Greene, 1988; Lapan & Reynolds, 1994; Lorch, Lorch, & Mogan, 1987; McCrudden, 2011; McCrudden, Magliano & Schraw, 2010; McCrudden & Schraw, 2007, 2009; McCrudden, Schraw, & Kambe, 2005; Rothkopf & Billington, 1979; van den Broek, Lorch, Linderholm, & Gustafson, 2001). A pesar de que Anderson y Pichert (1978) no encontraron resultados concluyentes en su estudio seminal en lo relativo al efecto de la perspectiva adoptada al leer un texto sobre una tarea de recuerdo sobre el mismo, muchos de los estudios realizados con posteridad sí que tuvieron éxito en detectar este efecto de la perspectiva, tanto cuando se analizaba durante el procesamiento lector como en la representación mental final de los textos. En uno de los estudios clásicos, Baillet y Keenan (1986) observaron el efecto de la perspectiva al inducir a los lectores a adoptar una perspectiva de lectura específica (e.g., la perspectiva de un ladrón o la de un diseñador de interiores), antes de comenzar a leer una historia que describía tres casas. Tras la lectura, los participantes debían recordar toda la información posible acerca de la historia de las casas. Los resultados del estudio mostraron que tener en mente una perspectiva de lectura específica determinaba el tipo de información recordada, ya que los lectores tendían a omitir de forma consistente la información irrelevante desde el punto de vista de la perspectiva adoptada.

Posteriormente, y empleando metodología de movimientos oculares, Kaakinen, Hyönä y Keenan (2002) pusieron a prueba el efecto de la perspectiva sobre un texto expositivo que describía cuatro países como posibles países de residencia. Los autores descubrieron que la perspectiva que se les daba a los lectores antes de leer el texto, hacía que éstos recordaran de manera selectiva más información relativa a ese país que a los demás. De igual modo, los patrones de movimientos oculares de los participantes mostraron también un procesamiento selectivo de aquellas secciones del texto que eran relevantes desde la perspectiva adoptada. En otro estudio de lectura de textos expositivos, Kaakinen y Hyönä (2005) analizaron los patrones de movimientos oculares y el recuerdo de participantes que leían un texto acerca de dos enfermedades raras. A los participantes se les facilitaron diferentes perspectivas relacionadas con una de las dos enfermedades que se trataban en el texto antes de leerlo. De nuevo, la perspectiva de lectura adoptada generó tiempos de fijación más largos en frases relevantes para la perspectiva durante la lectura inicial de las mismas. Adicionalmente, el recuerdo también fue mejor para la información relevante para la perspectiva adoptada que para la información no relevante para la perspectiva adoptada.

1.1.2. El papel de la "relevancia" del texto y del tipo de instrucciones

Del mismo modo que la información "relevante de un texto" puede determinarse bajo una determinada perspectiva, la información recordada también puede estar influida por la presencia de instrucciones de relevancia. Pero, ¿qué se entiende por relevancia? Para Sperber y Wilson (1986) la relevancia de un texto o de sus fragmentos, depende de los objetivos e intereses de los lectores. Más específicamente, Lehman y Schraw (2002) definen la relevancia como "la medida en la que los fragmentos del texto son pertinentes para el objetivo y los propósitos del lector" (p. 738), sugiriendo que los objetivos de lectura son factores fundamentales que determinan la relevancia que los lectores otorgan a cada fragmento del texto. Sea cual sea la fuente de la relevancia para un lector en una determinada situación, ésta tiene un papel fundamental en el procesamiento de los textos. De este modo, la relevancia puede favorecer que los lectores atiendan de manera más focalizada (Kaakinen & Hyönä, 2005; McCrudden, Magliano, & Schraw, 2010), o que atiendan de manera más eficiente a la información relevante (McCrudden, Schraw, & Kambe, 2005), mejorando de este modo su comprensión y memoria respecto a la información menos relevante.

También se ha desarrollado bastante investigación a lo largo de los últimos años en el estudio de instrucciones y de su efecto sobre la comprensión y memoria de textos (e.g., Kaakinen, Hyönä, & Keenan, 2003; Lorch, Klusewitz & Lorch, 1995; Lorch, Lorch, & Mogan, 1987; Narvaez, van den Broek & Ruiz, 1999). Estos estudios generalmente implican un conjunto de instrucciones previas a la lectura de un texto como, por ejemplo, leer para resumir o contestar a preguntas insertadas en el texto, que supuestamente dirigen a los lectores a segmentos específicos del texto. La investigación en este campo ha venido demostrando, de forma consistente, que el establecimiento de un objetivo de lectura tiene efectos beneficiosos en la forma en la que los lectores procesan los textos.

McCrudden y Schraw (2007) realizaron una revisión exhaustiva sobre el papel de las instrucciones de relevancia en el aprendizaje de textos. A raíz de esta revisión, los autores identificaron dos categorías principales de instrucciones de relevancia que los investigadores han utilizado, tanto de forma individual como combinada, que denominaron instrucciones de relevancia “generales” y “específicas” (ver McCrudden, Magliano, & Schraw, 2011, para una revisión completa).

Las “instrucciones generales de relevancia” (*general relevance instructions*) facilitan a los lectores la utilización de un marco de referencia amplio o general durante la lectura. Ejemplos de esto podrían ser leer para comprender, o leer con el objetivo de resumir las principales ideas del texto. Este tipo de instrucciones pueden proporcionar a los lectores un objetivo general para la lectura que puede a su vez influir en los tipos de procesamiento y en las inferencias que llevan a cabo (van den Broek, Lorch, Linderholm, & Gustafson, 2001; van den Broek, Risden, Husebye-Hartmann, 1995). Existen diversas demostraciones empíricas que muestran que las manipulaciones llevadas a cabo con instrucciones generales de relevancia tienen efectos consistentes tanto en el procesamiento del texto como en la posterior memoria para el mismo (Kaakinen & Hyönä, 2007, 2008, 2011; Lorch et al., 1987; McCrudden et al., 2005; Narváez et al., 1999; Rothkopf & Billington, 1979; van den Broek et al., 2001). A pesar de que muchos hallazgos relacionados con el efecto que las instrucciones generales de relevancia tienen sobre la forma en la que los lectores procesan los textos, algunas de estas manipulaciones no siempre producen los efectos esperados (Graesser & Nakamura, 1982; Zwaan, Magliano, & Graesser, 1995). En este sentido, las instrucciones generales de relevancia están frecuentemente abiertas a interpretaciones alternativas, ya que distintos lectores, recibiendo las mismas instrucciones, pueden desarrollar diferentes objetivos de lectura y emplear distintas estrategias para alcanzarlos (McCrudden et al., 2010). Por ejemplo, el hecho de facilitar una instrucción general como realizar un resumen del texto, puede llevar a los lectores a generar resultados diferentes. Así, por ejemplo, algunos lectores podrían elaborar una síntesis de las principales ideas de todo el texto; otros podrían tratar de replicar fragmentos explícitos extraídos del texto e, incluso, algunos lectores podrían añadir sus opiniones acerca del contenido del texto (León & Escudero, 2015).

Por su parte, las "instrucciones específicas de relevancia" (*specific relevance instructions*) establecen objetivos de lectura que focalizan una parte concreta del contenido del texto como relevante. Esta clase de instrucciones son típicamente menos ambiguas que las instrucciones generales de relevancia, por lo que los lectores las interpretan de manera más consistente (McCrudden & Schraw, 2007). Ejemplos clásicos de instrucciones específicas de relevancia incluyen leer para contestar a preguntas presentadas antes de la lectura o leer para contestar a preguntas que se presentan dentro del texto. Otro método que ofrece buenos resultados a la hora de facilitar el aprendizaje de textos expositivos consiste en instruir a los lectores para buscar respuestas a preguntas de tipo "por qué" (*why* questions) durante el transcurso de la lectura. Este método se conoce también como "interrogación elaborativa" (*elaborative interrogation*) y se puede entender como un caso concreto dentro de las instrucciones específicas de relevancia (McCrudden & Schraw, 2007).

A lo largo de los últimos años se ha desarrollado una importante cantidad de investigación donde se muestran los beneficios de este método en los procesos de lectura, y también en la mejora de la comprensión y de la memoria sobre los textos leídos (Callender & McDaniel, 2007; Cerdán, Vidal-Abarca, Martínez, Gilabert, & Gil, 2009; Graesser, 2007; Graesser & Lehman, 2011; Kaakinen, Lehtola & Paattilammi, 2015; Levin, 2008; Lewis & Menskink, 2012; Martin & Pressley, 1991; Smith, Holliday & Austin, 2010; Wiley, Goldman, Graesser, Sanchez, Asch & Hemmerich, 2010; Woloshyn, Pressley, & Schneider, 1992; Wood Wood, Pressley & Winne, 1999). El propósito a la hora de emplear preguntas de tipo "por qué" es mejorar el aprendizaje incitando a los lectores a establecer relaciones con el conocimiento previo o con la información leída en el texto. Dado que contestar a preguntas de este tipo típicamente requiere sintetizar información del texto y establecer vínculos entre diferentes secciones del mismo y/o activación de conocimiento previo, este método puede mejorar la comprensión porque dirige al lector a un nivel de codificación de la información del texto que va más allá del nivel superficial o proposicional (e.g., Graesser, 2007). En un estudio llevado a cabo por Wood et al. (1990), los niños que generaban respuestas a preguntas de tipo “por qué” mientras leían mostraban mejor recuerdo sobre los hechos planteados en los textos. Seifert (1993) encontró que los lectores a los que se les presentó una pregunta de tipo “por qué” en un pasaje y se les instruyó para contestar a esa pregunta después de leer, mostraron una mejora en el recuerdo de las ideas principales presentadas en el texto. Adicionalmente, McDaniel y Donnelly (1996) mostraron en su estudio que el método de la interrogación elaborativa también puede mejorar el proceso de generación de inferencias. Los autores sugirieron que el método de interrogación elaborativa mejora también la construcción del modelo situacional de los contenidos del texto, lo cual implica que los lectores van más allá de la información presentada en el texto, generando inferencias para formar un mejor modelo mental de la información presentada en el texto (Kintsch, 1998). En un estudio posterior empleando movimientos oculares, Lewis y Mensink (2012) mostraron que los participantes incrementaban las duraciones de sus primeras fijaciones y también de fijaciones posteriores en frases relevantes para contestar a una pregunta de tipo “por qué” presentada antes de la lectura. Estos lectores también incluyeron más información extraída de las frases relevantes para contestar a la pregunta en una tarea de recuerdo posterior. Por su parte, en el estudio de Smith, Holliday y Austin (2010), los estudiantes que recibieron preguntas de tipo “por qué” mientras leían textos expositivos obtuvieron mejores resultados in una tarea de comprensión que aquellos estudiantes que únicamente podían releer los materiales del texto. Adicionalmente, en otro estudio de movimientos oculares, Kaakinen, Lehtola y Paattilammi (2015), los autores encontraron que las preguntas de tipo “por qué”, cuando se presentaban a modo de títulos de cada pasaje, facilitaban la primera lectura del texto, y también incrementaban el procesamiento de tipo integrador entre las distintas frases de un mismo pasaje, como quedó reflejado en el incremento de la tasa de refijaciones.

1.2. Modelos de instrucción y efectos sobre la comprensión y la memoria

Dada la importancia que están teniendo los modelos más recientes en el campo de las instrucciones y la relevancia que poseen en el procesamiento de textos expositivos, y sus explicaciones sobre los procesos de comprensión lectora y de memoria, dedicaremos este apartado a describir brevemente algunos de estos modelos.

1.2.1. Goal focusing model (McCrudden & Schraw, 2007, 2010)

McCrudden y Schraw proponen un modelo de cuatro estadios para explicar el efecto de relevancia. El primer estadio del modelo consiste en **pistas de relevancia** explícitas o implícitas que alertan al lector sobre la relevancia de ciertos tipos de información y que lleva a diferenciar entre información de alta y de baja relevancia. Señales explícitas pueden consistir en señalizadores dentro del texto (véase León & Carretero, 1992, 1995), señales verbales facilitadas por los profesores, o algún tipo de directriz específica para la lectura. Por su parte, las señales implícitas pueden incluir el orden de presentación de la información, o la repetición. Las señales de relevancia pueden inducir al lector a cambiar el tipo de estrategia que utiliza durante la lectura, haciendo que ésta dependa de la relevancia de segmentos concretos del texto para un objetivo de lectura específico o general.

El segundo estadio del modelo consiste en la **focalización de objetivos.** Durante esta etapa, las instrucciones de relevancia ayudan a los lectores a generar objetivos de lectura específicos y a desarrollar estrategias de búsqueda de tipos específicos de información que son relevantes para sus objetivos. Los autores proponen que los lectores establecen ciertos estándares para el nivel de comprensión que tratan de alcanzar cuando tienen que construir una representación en la memoria sobre la información leída, y que estos estándares se desarrollan en parte debido a la relevancia. Gracias a la focalización de objetivos, los lectores van generando estos estándares de relevancia tanto antes de leer el texto como durante la lectura del mismo, determinando de este modo la relevancia de los distintos fragmentos del texto.

El tercer estadio consiste en la toma de decisiones sobre la **asignación de recursos.** Los lectores deben juzgar constantemente la relevancia de cada fragmento del texto, y contrastar si la representación mental resultante es consistente con su objetivo de comprensión. Los lectores deben decidir si los distintos fragmentos del texto son consistentes con sus estándares de relevancia o, por contra, si los criterios deben ser actualizados o modificados. Se asume que la decisión de iniciar o de realizar determinados procesos mentales durante la lectura para alcanzar la comprensión del texto está bajo el control del lector. Los estándares de relevancia ayudan, y mucho, al lector a seleccionar la información relevante y a construir una representación mental coherente sobre su comprensión del texto.

Finalmente, el cuarto y último estadio consiste en el **aprendizaje** y la construcción de representaciones mentales. Las instrucciones de relevancia ayudan a los lectores a dotar de mayor relevancia a unos fragmentos del texto sobre otros y, como consecuencia, a desarrollar una mejor comprensión de la información contenida en el mismo. Las instrucciones de relevancia parecen facilitar varios tipos de aprendizaje de los textos, como el aprendizaje de información objetiva, el aprendizaje de conceptos o también cómo aprender a generar ideas principales del texto mediante inferencias. Incluso las instrucciones de relevancia inducen a un aprendizaje más profundo basado en las conexiones causales entre los principales argumentos del texto. Según los autores, una de las posibles explicaciones para el efecto que causan las instrucciones de relevancia en el aprendizaje es que estas instrucciones facilitan la formación de criterios para evaluar la relevancia del texto en función de las metas de los lectores. De este modo, conforme los lectores desarrollan los criterios para evaluar la relevancia de los distintos segmentos del texto, la información del mismo que cumple con los criterios de los lectores estará organizada de manera significativa y será más accesible desde la memoria.

Resumiendo, el presente modelo establece que las instrucciones de relevancia comunican información al lector sobre la tarea de lectura, información que es interpretada por el mismo, desarrollando un objetivo de lectura que está relacionado con la tarea. El lector destina recursos mentales a actividades dirigidas a cumplir con ese objetivo de lectura establecido, y, finalmente, una ejecución eficiente de estas habilidades termina produciendo un efecto sobre lo que se aprende.

1.2.2. Focus assumption model (Graesser & Lehman, 2011)

Los autores proponen que la comprensión está guiada por preguntas, partiendo de la idea de que, tras todo objetivo de lectura, siempre hay una pregunta. De este modo, la comprensión guiada por objetivos puede entenderse como formular y responder a preguntas. El modelo planteado predice que la atención, el esfuerzo y la elaboración conceptual se focalizarán en la información del texto enmarcada en el campo receptivo, a costa de descuidar la información que quede fuera del mismo. Es decir, se trata de un proceso de atención selectiva. De esta manera, y, según este modelo, en una tarea de lectura, se dedicará más atención y codificación a la información que esté en el campo receptivo de la pregunta adjunta que a la información que quede fuera de ella. De este modo, la consecuencia será que la información relevante para la pregunta planteada será mejor comprendida y recordada que la información incidental o irrelevante para la pregunta. Los autores han llevado a cabo varios estudios empleando la metodología de movimientos oculares en los que han confirmado los supuestos de su modelo (e.g., Wiley et al., 2010; Graesser, Lu, Olde, Cooper-Pye, & Whitten, 2005).

1.2.3. Perspective-driven text comprehension framework (Kaakinen & Hyönä, 2008)

Los autores proponen un modelo de comprensión de textos basado en el efecto de la perspectiva del lector. El modelo presenta el efecto de la perspectiva en la comprensión de textos, describiendo las relaciones entre conocimiento, atención y memoria durante condiciones de lectura guiada por objetivos.

La idea central del modelo es que un input de tipo sensorial, como puede ser un texto, activa de forma automática ciertos elementos en la memoria a largo plazo. Estos elementos que han sido activados en la memoria a largo plazo se activan principalmente en el foco atencional, aunque no todos lo hacen con la misma intensidad, puesto que la capacidad es limitada. De este modo, los autores asumen que existen mecanismos de control desde el ejecutivo central que permiten mantener la activación de estos elementos o desactivarlos, en función de los requisitos de la tarea que se esté llevando a cabo. Desde este modelo, se plantea que las instrucciones de perspectiva o el objetivo de lectura adquirido activan, por tanto, conceptos relevantes en la base de conocimientos de los lectores. Las instrucciones de la tarea de lectura también establecen los estándares de coherencia para la representación que se forma en la memoria sobre los contenidos del texto que se ha de leer. Durante el curso de la lectura, la información del texto se está interpretando constantemente a la luz del conocimiento activado, y también de los estándares de coherencia establecidos. Cuando el lector se fija en una palabra, el significado de la palabra se codifica, y también se activan conceptos relacionados y conocimiento previo relevante. Según el modelo, cuando se encuentra información en el texto acorde para la perspectiva de lectura adoptada, las estructuras de conocimiento activadas en la memoria a largo plazo resuenan con el input del texto, permitiendo un reconocimiento rápido de la información del texto como relevante. De este modo, la información del texto relevante para la perspectiva adoptada se incorpora fácilmente a la representación mental del texto que se va desarrollando, cumpliendo con los estándares de coherencia establecidos. Por su parte, la información irrelevante para la perspectiva será procesada de manera superficial, por lo que el lector no tratará de integrar esta información en la representación mental en desarrollo. Tal y como los autores señalan, establecer los enlaces necesarios para incorporar la información del texto en la representación en la memoria que se va desarrollando durante la lectura no es una tarea sencilla, y requiere de un esfuerzo atencional consciente. De este modo, el lector puede decidir releer la información relevante antes de seguir avanzando en la lectura del texto, así como detenerse brevemente al final de esa sección para permitirse un tiempo adicional para la integración.

Continuando con los supuestos del modelo, el ejecutivo central debe ser responsable de dirigir los recursos atencionales necesarios para cumplir con los objetivos de la tarea de lectura. Para lograr un entendimiento suficiente de los contenidos del texto, las estructuras de conocimiento deben activarse para facilitar las inferencias necesarias, partes de la representación formada del texto han de llevarse al foco atencional, y la perspectiva y/o el objetivo de lectura será reactivado si su nivel de activación ha caído y el lector está en proceso de evaluar la relevancia de un elemento del texto. El ejecutivo central también supervisa la atención visual y es el responsable de adaptar las estrategias de lectura a los objetivos establecidos, ya sea para reprocesar la información del texto si es necesario, o para suspender el ingreso de nueva información en el caso de que no se haya logrado todavía una comprensión suficiente de la parte del texto que se está procesando en ese momento. La representación en la memoria sobre los contenidos del texto se acumula a medida que las estructuras de conocimiento se activan en la memoria a largo plazo. Algunas se recuperan directamente de la memoria a largo plazo mediante el proceso de resonancia, mientras que otros conceptos se pueden recuperar mediante la búsqueda en la memoria o haciendo inferencias. De este modo, la representación del texto resultante en la memoria implicará todas las trazas de memoria activadas durante la lectura de una forma u otra.

Los autores han llevado a cabo varios estudios de movimientos oculares cuyos resultados están en línea con los supuestos del modelo propuesto, que indican además que todo lo planteado es válido y aplicable tanto para textos expositivos como para textos narrativos (e.g., Kaakinen & Hyönä, 2008).

1.2.4. RESOLV Framework (Britt, Rouet, & Durik, 2017)

Los autores proponen un modelo para describir la lectura que ellos consideran intencional, es decir, la lectura conlleva siempre una intencionalidad. Para estos autores, la lectura intencional consiste básicamente en una situación de resolución de problemas, que puede ser entendida como una actividad dirigida por objetivos enmarcada en un contexto situacional, cuyo objetivo final es la comprensión de lo leído, que conlleva la resolución de los problemas (de comprensión). Los autores plantean que la lectura intencional se basa siempre en la representación mental que los lectores se forman sobre la tarea y el contexto, y, por consiguiente, que esas representaciones internas son las que guían a decisiones y a procesos específicos de lectura. Según este marco teórico, una vez el lector ha interpretado el contexto de lectura, este contexto junto a la motivación específica del lector, determinan el objetivo de lectura y el tipo de información que el lector extraerá del texto. Una de sus premisas básicas es que un fallo en la lectura intencional no tiene por qué deberse siempre a una representación pobre de los contenidos del texto, sino a representaciones pobres o inadecuadas de la tarea y del contexto de lectura.

Dentro de este marco teórico, los autores distinguen entre tres tipos de representaciones mentales internas o modelos que el lector desarrolla a lo largo de la tarea de lectura y que denominan, “modelo contextual”, “modelo de la tarea” y “modelo de documentos”. El modelo contextual constituye el primer nivel de representación mental y alude a que los lectores generalmente participan de la lectura porque experimentan señales tanto explícitas como implícitas que les llevan a interpretar estas señales respecto a su contexto físico y social; de ahí la denominación de “contextual”. Para generar este modelo contextual el lector debe elaborar un grupo de representaciones mentales sobre su estado actual, sobre el estado de sus objetivos, y un plan para llevar a cabo esos objetivos. Este modelo contextual consta, a su vez, de cinco categorías de representaciones mentales más básicas, como una representación de la tarea de lectura, una representación de la persona que ha solicitado la tarea de lectura, una representación de la persona que la recibe, conocimiento sobre la tarea y sobre los obstáculos que podrían impedir completarla, y una representación de los costes y beneficios percibidos por el lector, en base a su propia habilidad, conocimiento o interés.

Un segundo nivel de representación corresponde al **modelo de la tarea**, cuyo papel es fundamental en la lectura, ya que dirige al lector a tomar decisiones sobre qué leer y cómo hacerlo. El modelo de la tarea es la representación interna que el lector desarrolla sobre la meta de lectura a alcanzar y sobre las estrategias necesarias para llevarla a cabo con éxito. De esta manera, y mientras el modelo contextual proporciona un plan sobre cómo un cierto tipo de tarea de lectura se puede completar a nivel general, el modelo de la tarea sería un refinamiento adicional, basado en las oportunidades y las restricciones de la situación específica y de la tarea. La calidad del modelo de la tarea que un lector desarrolle dependerá de varios factores, como la experiencia del lector con tareas similares, el nivel de interés, la motivación por la tarea actual y la habilidad para extraer pistas del contexto. Como es de esperar, variaciones en la calidad del modelo de la tarea tendrán su efecto en lo que la gente lee, en cómo lo lee, en cómo comprende, y finalmente en sus probabilidades para completar con éxito sus objetivos de lectura.

Por último, un tercer nivel de representación es el **modelo de documentos**. Este modelo es, en palabras de los autores, la representación interna que el lector desarrolla sobre la información textual que será empleada para la tarea de lectura, incluyendo representaciones sobre las fuentes y también sobre el contenido.

A modo de resumen, el modelo plantea una explicación teórica sobre la lectura que tiene en cuenta las interacciones entre los lectores, los textos y los contextos, explicando el proceso de lectura intencional como una situación de solución de problemas para lograr una serie de objetivos de lectura concretos. Para llevar a cabo con éxito la tarea de lectura, según los autores, el lector desarrolla durante la misma tres tipos diferentes de representaciones mentales internas, como son la representación del contexto de lectura (modelo contextual), la representación de la tarea de lectura (modelo de la tarea), y la representación del contenido del texto y de la fuente de información relacionados con la tarea de lectura (modelo de documentos).

1.3. El estudio de la lectura a través de la metodología de los movimientos oculares

En este último apartado de la presente introducción teórica, se planteará en términos generales en qué consiste el estudio de los procesos de lectura a través de la metodología de los movimientos oculares, exponiendo datos sobre algunos de los estudios más importantes llevados a cabo en el campo, y describiendo las principales medidas de movimientos oculares que se emplean con mayor frecuencia en el estudio de la lectura, así como las correspondencias con los procesos que pretenden describir.

Cuando leemos en distintas lenguas, como pueden ser el castellano o el inglés, lo hacemos siempre de izquierda a derecha y de arriba abajo. De manera intuitiva, podemos tener la creencia a priori de que nuestros ojos recorren el texto de manera lineal desde el principio hasta el final del mismo, recorriendo y procesando cada una de las frases de forma constante y de principio a fin hasta terminar de leer la totalidad del texto. Al analizar los movimientos oculares que un lector lleva a cabo durante la lectura de un texto, comprobamos que éstos son mucho más complejos de lo que cabría esperar, y que reflejan algunas de los procesos mentales más importantes que se están llevando a cabo a lo largo del proceso de lectura. En palabras de Rayner (1998, 2009), cuando leemos, miramos una escena, o buscamos un objeto, estamos constantemente llevando a cabo un tipo de movimientos oculares denominados sacadas o **movimientos sacádicos** (*saccades*), que consisten en movimientos rápidos que realizamos en forma de segmentos de mirada muy reducidos, en los que abarcamos una pequeña sección de información del texto o de la escena que estamos analizando, y que coincide con nuestro rango de visión central o foveal. En condiciones de lectura natural, la longitud de un movimiento sacádico suele ser aproximadamente entre 7-9 caracteres, incluyendo espacios y caracteres alfanuméricos. Entre estos movimientos sacádicos, nuestros ojos van llevando a cabo también de forma constante otro tipo de movimientos oculares llamados **fijaciones** (*fixations*), que consisten en pequeñas paradas que hacen los ojos entre el final de un movimiento sacádico y el inicio del siguiente. La duración promedio de estas fijaciones suele ser de entre 200 y 300 ms. en condiciones de lectura natural, y suelen realizarse generalmente en caracteres situados en torno al centro de las palabras que se están procesando.

La función principal de los movimientos sacádicos es la de dirigir la visión foveal a una nueva región de texto, para realizar un análisis más detallado de esa región del texto.

Mientras que la mayor parte de las palabras en un texto son fijadas al menos una vez durante la lectura, hay algunas palabras que se saltan (*word skipping*), puesto que no es necesario el procesamiento foveal de cada una de las palabras. Aproximadamente, se fija el 85% de las palabras de contenido, mientras que solo se fija el 35% de las palabras funcionales (e.g., Rayner & Duffy, 1988). Las palabras funcionales (e.g., proposiciones) se suelen fijar menos que las palabras de contenido, en parte porque tienden a ser palabras más cortas, y existe una relación entre la probabilidad de fijar una palabra y su longitud, en el sentido de que a medida que la longitud de una palabra aumenta, aumenta también la probabilidad de que esa palabra sea fijada (Rayner & McConkie, 1976). Palabras de 2 a 3 caracteres únicamente se fijan el 25% de las veces, mientas que palabras de 8 caracteres o más se fijan prácticamente en todas las ocasiones, y, generalmente, incluso más de una vez. A pesar de que la mayor parte de los movimientos sacádicos en lectura de inglés o castellano se llevan a cabo de izquierda a derecha, los lectores no siempre avanzan hacia adelante. De hecho, aproximadamente el 15% de los movimientos sacádicos se consideran **regresiones** (*regressions*), que son movimientos sacádicos que se llevan a cabo de derecha a izquierda en la misma línea del texto, o incluso movimientos sacádicos dirigidos a líneas anteriores que ya han sido leídas previamente (Rayner, 1998, 2009). Muchas regresiones suelen ser de unos pocos caracteres y pueden deberse a que el lector ha llevado a cabo un movimiento sacádico hacia adelante demasiado largo, por lo que un pequeño movimiento sacádico hacia la izquierda puede ser necesario para leer de forma eficiente. Las regresiones de pocos caracteres también pueden deberse a que el lector ha podido tener problemas procesando la palabra actual y necesite fijarse de nuevo en ella. Por su parte, se consideran regresiones largas cuando son de más de 10 caracteres dentro de la misma línea o en líneas anteriores, y se dan generalmente cuando el lector no ha comprendido alguna sección del texto (Rayner, 1998, 2009). En estos casos, los buenos lectores son muy precisos dirigiendo sus ojos hacia la parte del texto que les ha causado esa dificultad (e.g., Murray & Kennedy, 1988), mientras que los lectores más pobres tienden a retroceder más allá en el texto (Murray & Kennedy, 1988).

Uno de los puntos clave en relación a las medidas de movimientos oculares es que pueden emplearse para inferir los procesos cognitivos que se producen durante el transcurso de la lectura, reflejando la variabilidad de esas medidas el procesamiento online de los lectores (e.g., Just & Carpenter, 1980). Por ejemplo, hay evidencias de que la frecuencia de una palabra fijada influye en cuánto tiempo dedican los lectores a fijarse en esa palabra (e.g., Rayner & Duffy, 1988), por lo que las propiedades de la palabra fijada tenderán a modular el tiempo de fijación, lo que desembocará en variabilidad en los tiempos de fijación más generales. Como señala Rayner (2009), el procesamiento léxico y los procesos de comprensión de alto nivel son los motores que dirigen a los ojos a lo largo del texto. Cuando los lectores se enfrentan a situaciones de ambigüedad sintáctica, la duración de sus fijaciones se incrementa, y tienden a hacer movimientos sacádicos más cortos y un mayor número de regresiones (Rayner & Sereno, 1994). En casos como estos, los procesos de comprensión de alto nivel toman el control sobre la situación normal en la que el procesamiento léxico dirige los ojos, lo cual resulta en el citado incremento en la duración de las fijaciones o en el incremento en las regresiones que se dan a partes anteriores del texto.

1.3.1. Principales medidas de movimientos oculares para estudiar el procesamiento de textos

Respecto a las principales medidas de movimientos oculares que se suelen emplear para analizar cómo los lectores procesan los textos, Hyönä, Lorch y Rinck (2003) distinguen entre medidas que indican efectos inmediatos y medidas que indican efectos demorados de procesamiento. En el estudio del procesamiento léxico, los citados efectos inmediatos en el procesamiento se suelen medir mediante la duración de la "primera fijación" (*duration of the first fixation*) en la unidad de texto que se esté analizando (generalmente palabras). Otra de las medidas que más se suelen emplear, la "duración de la mirada" (*gaze duration*), refleja también efectos inmediatos en el procesamiento y consiste en la suma de cada una de las fijaciones individuales en la región del texto que se está analizando antes de salir de ella. Cuando se da una única fijación en la unidad de texto analizada, la duración de la mirada es equivalente a la duración de la primera fijación. Cuando se dan "refijaciones" (*refixations*), la duración de la mirada refleja efectos menos inmediatos que la duración de la primera fijación. Para el caso de los efectos demorados, existen varias medidas que se usan con frecuencia, tales como la "duración de la primera fijación" (*first fixation duration*) después de haber dejado la unidad de texto que se está analizando, la "duración de las regresiones" (*look back duration*) de vuelta a esa región del texto, y el "tiempo total de fijación" (*total fixation time*) calculado como la suma de la duración de la mirada y de la duración de las regresiones. Todas estas medidas de efectos demorados reflejan eventos en el comportamiento lector después de que se haya abandonado la región del texto que se está analizando. Por último, el "tiempo total de fijaciones" (*total fixation time*) es una medida combinada que junta ambos, efectos inmediatos y demorados. En el caso del procesamiento sintáctico, las potenciales unidades de análisis aumentan, pasando por varios niveles que van desde la palabra hasta una oración completa con significado o incluso un párrafo (Hyönä, Lorch, & Rinck, 2003). En relación al incremento en el tamaño de las unidades de análisis, se asume que los procesos mentales relacionados con este procesamiento sintáctico serán más complejos y variados, por lo que los movimientos oculares que se lleven a cabo a raíz de ellos serán a su vez más complejos también. En su revisión, Hyönä y compañía vuelven a distinguir en este caso entre efectos inmediatos y demorados en el procesamiento, que se estudian mediante medidas de movimientos oculares conocidas como medidas de primera pasada (*first-pass measures*) y medidas de segunda pasada (*second-pass measures*) respectivamente, para la región del texto que sea de interés estudiar. El "tiempo de fijación de primera pasada" (*first-pass fixation time*) para una región determinada del texto se define, según los autores, de forma análoga a la previamente descrita duración de la mirada, siendo nuevamente la suma del tiempo de fijación para una determinada región del texto antes de dejarla. Por su parte, el "tiempo de fijación de segunda pasada" (*second-pass fixation* *time*) refleja efectos de procesamiento demorados, al igual que la medida sobre la duración de las regresiones previamente descrita. Esta medida consiste en el resultado del sumatorio de las fijaciones que vuelven a una región del texto después de ésta haya sido fijada al menos una vez.

1.3.2. Estrategias de lectura y de procesamiento de textos

En los primeros apartados de la presente introducción se ha tratado de dar una visión global sobre los principales tipos de instrucciones y de señalizadores que se pueden emplear en contextos instruccionales para facilitar a los lectores la comprensión de textos expositivos. Pese al impacto que este tipo de instrucciones de relevancia tienen sobre el procesamiento lector, la comprensión y la memoria, una parte del desempeño en la tarea de lectura va a depender también del nivel de competencia del propio lector. De este modo, tal y como establecen Hyönä, Lorch y Kaakinen (2002), los lectores pueden diferir en su sensibilidad a la hora de detectar la información relevante para el tema del texto mientras leen, y, por consiguiente, pueden emplear del mismo modo distintas estrategias de procesamiento cuando se encuentran ante una tarea de lectura de textos expositivos. Según estos autores, una estrategia inteligente de procesamiento de los distintos temas dentro de un mismo texto consistiría en emplear pistas provenientes de la estructura del texto, señalizadores tales como encabezados, pistas sintácticas que puedan denotar transiciones entre los distintos temas, y saltos en la coherencia que pueden también ayudar a identificar nuevos temas. Una vez identificado un tema nuevo, el lector construye una representación del mismo y establece relaciones con el resto de temas anteriores que conforman el texto que está procesando. Basándose en los resultados de investigaciones previas en el campo (tales como las llevadas a cabo por Goldman & Saul, 1990 y Vauras, Hyönä, & Niemi, 1992), Hyönä y compañía (2002) proponen que los lectores más competentes emplean una **estrategia de procesamiento selectiva** (*selective processing strategy*), mediante la cual éstos dedican recursos de procesamiento adicionales tanto en la lectura inicial (*first-pass reading*) como en las relecturas (*second-pass reading*) a las secciones del texto que están representando transiciones entre los distintos temas que lo componen, tales como encabezamientos, frases relevantes para el tema, o frases que denotan finalización de una determinada sección. Por su parte, los lectores menos competentes utilizan una **estrategia de procesamiento no selectiva** (*nonselective processing strategy*), ya que no prestan especial atención durante la lectura inicial a la información relevante para los temas del texto, ni tampoco a los encabezamientos o frases introductorias, ni a las frases que indican la finalización de una sección determinada del texto. Los lectores que emplean este tipo de estrategias pueden presentar dos tipos de patrones respecto a las relecturas, ya que algunos de ellos directamente no realizarán relecturas, mientras que otros sí las realizarán, pero sin dedicar especial atención a las secciones relevantes del texto en ningún punto de la lectura del mismo (Hyönä et al., 2002).

A modo de resumen, y, tal y como los propios autores concluyen en su estudio empírico, cabe resaltar que incluso entre lectores competentes, existen diferencias individuales en lo que a estrategias de lectura y de procesamiento de textos se refiere, y estas estrategias quedan reflejadas en los distintos patrones de movimientos oculares que los lectores realizan durante la tarea de lectura.

2. OBJETIVOS

En este apartado trataremos de dar una visión general sobre los principales objetivos y planteamientos de la presente tesis doctoral, que desembocan directamente en cada uno de los estudios que se han desarrollado dentro del marco de trabajo de la misma, y se tratará adicionalmente de ofrecer una visión general sobre los principales aportes o innovaciones incluidos en los distintos estudios.

El objetivo principal que se tratará de desarrollar a lo largo de los distintos estudios es el de analizar el efecto de las instrucciones de relevancia y de preguntas adjuntas sobre las estrategias de procesamiento y la comprensión lectora de textos expositivos mediante la metodología de los movimientos oculares. A diferencia de otros estudios que se han llevado a cabo en este campo, los trabajos desarrollados en la presente tesis emplean el párrafo como la principal unidad de análisis en el texto, lo cual implica trabajar fragmentos más amplios de lo que se suele analizar, que pueden ser más informativos a la hora de estudiar las estrategias de procesamiento.

Adicionalmente, cabe resaltar que la gran mayoría de los estudios que han venido analizando en los últimos años los efectos de las instrucciones de relevancia y de las preguntas adjuntas se han llevado a cabo registrando los tiempos de reacción de los lectores mediante el uso de pruebas cronométricas. Sin embargo, muy pocos lo han hecho llevando a cabo un análisis pormenorizado de los patrones de movimientos oculares en el procesamiento de los textos. Analizar el procesamiento lector mediante los movimientos oculares en lugar de hacerlo con tiempos de reacción conlleva múltiples ventajas, ya que los lectores tienen total libertad para llevar a cabo la tarea de lectura sin necesidad de llevar a cabo otro tipo de tarea ajena a la lectura como, por ejemplo, tener que pulsar un botón cada vez que han leído una sección del texto.

Adicionalmente, la metodología de movimientos oculares proporciona un protocolo de análisis de los procesos de lectura que evoluciona en el espacio y en el tiempo. Esta metodología también permite separar entre los movimientos realizados durante la primera lectura de las distintas secciones del texto (*first-pass reading*) y los movimientos realizados durante las relecturas (*second-pass reading*) (e.g., Hyönä et al., 2003). En definitiva, tal y como se ha tratado de exponer en líneas anteriores, la metodología de análisis de los movimientos oculares ha demostrado ser un método informativo y fiable para analizar una gran variedad de procesos relacionados con la lectura y la comprensión de textos (e.g., Hyönä, et al. 2003; Rayner, 1998; Rayner & Liversedge, 2011) y, por ello, será el método empleado para analizar los procesos de lectura en los estudios desarrollados en la presente tesis doctoral.

Por otra parte, cabe resaltar uno de los aportes a nivel metodológico de los estudios que aquí se desarrollarán, y es que, hasta la fecha, a pesar de existir una gran variedad de estudios que analizan los efectos de instrucciones de relevancia y de preguntas adjuntas en el procesamiento de textos expositivos, pocas veces se han estudiado combinando medidas online como la metodología de movimientos oculares, con medidas offline como la calidad del recuerdo para la lectura de distintos textos expositivos. Creemos que este es un avance metodológico respecto a la literatura previa, ya que la combinación de ambos tipos de medidas puede ser informativa y ofrecer un mejor entendimiento sobre los procesos de lectura y la posterior representación en la memoria, y también sobre las principales estrategias que se inducen al presentar los distintos tipos de instrucciones de lectura. Adicionalmente, puede ser útil para establecer vínculos de consistencia entre los procesos de lectura y los patrones en el recuerdo, ya que es esperable una relación estrecha entre los patrones de lectura, reflejados en las medidas de movimientos oculares, y la información incluida en los resúmenes de los textos realizados por los lectores. De este modo, en el caso de un lector que emplee una estrategia de lectura selectiva y que dedique fijaciones más largas y numerosas a la información del texto relevante para las instrucciones y para las preguntas adjuntas, sería de esperar que, del mismo modo, este lector incluyera más información relevante para las instrucciones o para las preguntas adjuntas en su representación final en la memoria que información irrelevante para la tarea.

Por último, cabe señalar también que, en algunos de los estudios incluidos en esta tesis, se ha pasado de aplicar modelos estadísticos más tradicionales o conservadores como son los modelos de análisis de varianza (ANOVA), a emplear modelos estadísticos más robustos, eficientes y modernos, como son los modelos lineales de efectos mixtos (*mixed effects models*). Estos modelos han demostrado ser más eficientes y ofrecer unos resultados más fiables y precisos a la hora de analizar todo tipo de datos relacionados con el procesamiento lector, y presentan ventajas sólidas respecto a los modelos de análisis de varianza tradicionales (e.g., Baayen, 2008; Bates, Maechler, Bolker, & Walker, 2015; Pardo & Ruíz, 2012). En primer lugar, lo más destacable de estos modelos es que son modelos multinivel, por lo que permiten estudiar tendencias a nivel individual a lo largo del tiempo, en lugar de estimar un modelo de crecimiento promedio en un solo análisis para todos los participantes. Adicionalmente, estos modelos también presentan diferencias en los métodos de estimación (máxima verosimilitud frente a mínimos cuadrados), ofrecen una mayor flexibilidad en el tratamiento de los valores perdidos, ya que permiten incluir casos de participantes en los que no todos los datos están disponibles, y favorecen también una mayor flexibilidad a nivel de supuestos en lo que respecta a la estructura de la matriz de varianzas-covarianzas.

A continuación, se ofrece una visión general de los principales objetivos específicos de cada uno de los estudios incluidos en la estructura de la presente tesis doctoral, algunos de ellos ya publicados o en prensa. Los objetivos enunciados en este punto se desarrollarán con mayor profundidad a lo largo de cada uno de los cuatro estudios que se citan a continuación.

2.1. Objetivos del estudio 1: *Age differences in eye movements during reading. Degenerative problems or compensatory strategy? A meta-analysis*

El presente estudio plantea tres objetivos principales, dos de ellos relacionados con los objetivos de investigación generales de esta tesis, y uno centrado en la propia pregunta de investigación del meta-análisis. En primer lugar, tratar de identificar y sintetizar cuáles son las medidas de movimientos oculares principales, más generales y más utilizadas, empleadas para analizar el procesamiento lector, dado que en la actualidad se emplean un gran número de ellas en función de los objetivos concretos de cada estudio y cada tarea de lectura. En segundo lugar, determinar qué grupos de edad son más competentes en tareas de lectura de textos expositivos, con la finalidad de aplicar las pruebas de los estudios empíricos de la presente tesis doctoral en una muestra de similares características. Por último, el objetivo de investigación del propio meta-análisis es comparar el rendimiento de dos grupos de edad distintos, adultos jóvenes y adultos mayores, en tareas de lectura de textos expositivos por medio del análisis de los patrones de movimientos oculares de ambos grupos, así como tratar de distinguir entre las principales estrategias de lectura que emplea cada uno de ellos.

En este estudio se muestran los resultados de un meta-análisis realizado sobre 22 experimentos en los que se comparan los datos de movimientos oculares obtenidos de lectores de dos grupos de edad diferentes, adultos jóvenes (21 años de media), y adultos mayores (73 años de media). Los datos incluyen un total de seis medidas de movimientos oculares (*mean gaze duration, mean fixation duration, total sentence reading time, mean number of fixations, mean number of regressions, and mean length of progressive saccade eye movements*).

2.2. Objetivos del estudio 2: *Specific relevance instructions promote selective reading strategies: Evidences from eye tracking and oral summaries*

En el presente estudio se aplica la metodología de movimientos oculares para analizar la influencia de instrucciones de relevancia en el procesamiento de secciones de texto relevantes e irrelevantes para una pregunta adjunta (*"why" question*) que se muestra siempre en el primer párrafo de cada texto. El objetivo principal de este estudio es el de analizar los efectos de estas instrucciones de relevancia, generales y específicas, sobre el procesamiento online registrado mediante medidas de movimientos oculares, así como el procesamiento offline, medido mediante una tarea de resumen oral relativa a la información del texto relevante para la pregunta adjunta, a lo largo de seis textos expositivos de temáticas diferentes sobre conocimiento general.

En este experimento se muestran los datos de 41 estudiantes universitarios, la mitad de ellos instruidos para realizar un resumen oral sobre las principales ideas reflejadas en cada texto, focalizando su respuesta en una pregunta adjunta que aparece siempre al final de cada primer párrafo (instrucción específica de relevancia), y la otra mitad de ellos instruida para llevar a cabo un resumen oral de las principales ideas del texto (instrucción general de relevancia).

2.3. Objetivos del estudio 3: *Impact of elaborative interrogation instructions on the processing of expository texts: An eye movement study*

En el presente estudio se plantea estudiar las estrategias de procesamiento inducidas por preguntas adjuntas (*"why" questions*) que se presentan al inicio de un pasaje. El objetivo principal de este experimento es estudiar de forma aislada el efecto que una pregunta adjunta puede tener sobre las estrategias de procesamiento lector y sobre la calidad de la representación final en la memoria. Se pretende estudiar el efecto que estas preguntas pueden tener tanto en el procesamiento online, representado mediante un conjunto de medidas de movimientos oculares que informan tanto de la primera lectura (*first-pass reading*) como de las relecturas (*second-pass reading*), como en el procesamiento offline, medido mediante una tarea de resumen oral relativa a la información del texto relevante para la pregunta adjunta, a lo largo de seis textos expositivos de temáticas diferentes sobre conocimiento general.

En este estudio se mantiene constante el tipo de instrucción presentada a los participantes, tratándose siempre de una instrucción específica de relevancia en todos los casos, y lo que se manipula es la presentación de la pregunta adjunta, al principio del texto, o mostrada después de leerlo. Se muestran los datos de 54 estudiantes universitarios instruidos para leer y resumir los textos expositivos centrándose siempre en la pregunta adjunta, que puede ser presentada en una de las dos posiciones previamente descritas.

2.4. Objetivos del estudio 4: *Relevance instructions combined with elaborative interrogation facilitate strategic reading: Evidence from eye movements*

En este último estudio se plantea un objetivo combinado, ya que se pretende estudiar tanto el efecto de las instrucciones específicas y generales de relevancia, como el efecto de las preguntas adjuntas (*"why" questions*) y la combinación de ambas sobre las estrategias de procesamiento y la calidad de la memoria. El planteamiento de partida del presente estudio radica en que es necesario estudiar si los efectos que ambas, instrucciones de relevancia y preguntas adjuntas, producen sobre las estrategias de procesamiento y sobre la calidad de la memoria se deben a las instrucciones específicas de relevancia que guían a focalizarse en la pregunta adjunta, o si pueden deberse únicamente a la propia presentación de las preguntas adjuntas, que pueden activar en los lectores de forma espontánea la necesidad de concentrarse en contenidos del texto que son relevantes para esas preguntas.

Por ello, en el presente estudio se plantean tres tipos diferentes de instrucciones a los participantes antes de leer un conjunto de seis textos expositivos que tratan sobre distintos temas de conocimiento general. En una de las condiciones, se instruye a los lectores a leer con el objetivo de producir un resumen oral sobre los principales contenidos del texto y para contestar a una pregunta adjunta que aparece al inicio del mismo (instrucción específica de relevancia). En la segunda condición, se instruye a los lectores a leer para posteriormente proporcionar un resumen oral sobre los principales contenidos del texto (instrucción general de relevancia). Los participantes de esta condición también reciben la pregunta al inicio del texto, pero no se les instruye específicamente para contestarla. Por último, en la tercera condición se instruye a los lectores para leer con el objetivo de resumir los principales contenidos del texto (instrucción general de relevancia), pero en este caso no reciben una pregunta adjunta al inicio del mismo, sino que encuentran una frase neutra en su lugar. Para este fin, en el presente estudio se muestran los datos de 105 estudiantes universitarios instruidos para leer y resumir textos expositivos.

3. ESTUDIOS

A continuación, se pasará a desarrollar en profundidad los cuatro estudios incluidos en la presente tesis doctoral que han sido previamente enunciados. Puesto que algunos de ellos ya han sido publicados o aceptados para publicación en revistas internacionales de impacto, y los demás también están siendo preparados y revisados para su publicación, se presentarán aquí todos ellos siguiendo la estructura de formato artículo científico en inglés. Las referencias específicas de cada estudio han sido eliminadas y, en su lugar, se ha creado un último apartado de bibliografía común para la totalidad de la tesis.

3.1. Age differences in eye movements during reading: Degenerative problems or compensatory strategy? A meta-analysis

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Abstract

We report the results of a meta-analysis of 22 experiments comparing the eye movement data obtained from young (mean age 21 years) and old (mean age 73 years) readers. The data included six eye movement measures (mean gaze duration, mean fixation duration, total sentence reading time, mean number of fixations, mean number of regressions, and mean length of progressive saccade eye movements). Estimates were obtained of the typified mean difference, *d*, between the age groups in all six measures. The results showed positive combined effect size estimates in favor of the young adult group (between 0.54 and 3.66 in all measures), although the difference for the mean number of fixations was not significant. Young adults make in a systematic way, shorter gazes, fewer regressions and shorter saccadic movements during reading than older adults, and they also read faster. The meta-analysis results confirm statistically the most common patterns observed in previous research, therefore eye movements seem to be a useful tool to measure behavioral changes due to the aging process. Moreover, these results do not allow us to discard either of the two main hypotheses assessed for explaining the observed aging effects, namely neural degenerative problems and the adoption of compensatory strategies.

Keywords: eye tracking, aging, multivariate meta-analysis, neural degenerative problems, compensatory reading strategies.

Introduction

Recent research has highlighted the fact that people's eye movement patterns during reading change with age (e.g., Rayner, Yang, Schuett & Slattery, 2013). In particular, comparisons have been made between two age groups, commonly known as young adults and older adults, to quantify these changes. The main results of these comparisons are consistent with the view that the aging process results in a number of physiological and/or pathological changes consistent with visual and cognitive deterioration. Despite these difficulties, older adults seem to marshal a set of compensatory cognitive strategies in order to minimize the effects of aging on the reading process.

Eye movement patterns that people make when they read have been studied for a long time in order to test theories of what is seen, what is comprehended, and what is remembered about what has been read (e.g., Just & Carpenter, 1976; Rayner & McConkie, 1976). All three components of reading can presumably be related to observable eye movement patterns, which differ across age. For example, some differences can be related to changes in visual acuity and visual perceptual abilities that tend to deteriorate as people get older (e.g., Dowiasch, Marx, Einhäuser & Bremmer, 2015). Research on visual changes with age has shown that saccadic latencies increase with age, and while reading, older persons tend to make more regressions and more and longer fixations (e.g., Rayner et al., 2013). Therefore, the present study begins with the idea that eye movements can be a good indicator of the changes that occur with advancing years in cognitive processes, and more specifically in reading, and ends with suggestions of some plausible explanations for the observed changes in reading patterns related to aging. Thus, this work aspires to be an informative synthesis in order to understand how our visual capabilities tend to deteriorate as we get older, focusing on the observation of any degenerative as well as compensatory behaviors manifested in the eye movements that people make while they are reading.

Whereas most saccadic movements proceed from left to right during normal reading, the reverse is true in 10% to 15% of the cases. Such saccades are called *regressions* (Rayner, 1998), which consist of saccades that move from right to left during reading in the same line or even jump to a previous line in the text. Moreover, regressions can be even larger than the typical forward saccade (more than 10 previous character spaces on the same line or even to previous lines), which could mean that readers have not understood the text. In such cases, competent readers are very precise, sending their eyes to the part of the text which they did not understood, while poorer readers usually go further back than necessary in the text while they are looking for information that reduces the uncertainty (Murray & Kennedy, 1988). On the other hand, fixations that occur at the beginnings and ends of each line do not exactly land on the first and last letter of that line, and the initial fixation is typically longer (Rayner, 1977) than any other made along the same line. Also, the final fixation is typically the shortest one of all. Similarly, readers almost never fixate on blank spaces between words in a line.

Regarding the comparison of reading eye movements between young and older adults, there are several differences that consistently appear in the literature. Specifically, older readers make more fixations while reading (Rayner, Castelhano & Yang, 2009, 2010), and these fixations are also longer than those made by young adults (Rayner, Yang, Castelhano & Liversedge, 2011). Older adults also tend to have longer saccades and tend to skip more words than young adults (Rayner, Reichle, Stroud, Williams & Pollatsek, 2006; Rayner et al., 2009). In addition, older readers tend to make more regressions to missed words than younger ones, and older adults read more slowly than young adults, as they generally dedicate more time to read the same amount of text (Stine-Morrow, Miller & Hertzog, 2006). Therefore, while eye guidance and fixation disparity may improve with maturation into earlier adulthood, poor saccadic control and increased fixation disparity may reemerge in later stages of life and become relevant aspects of difficulties experienced by older readers (Kliegl, Grabner, Rolfs, & Engbert, 2004; Stine-Morrow et al., 2006; Rayner et al., 2006, 2009).

Several explanations for age-related differences in cognition have been applied to previous research in word identification, word naming, and reading. Although older readers generally read more slowly than younger readers, in many other aspects their reading may be similar to that of younger readers (e.g., Rayner et al., 2006). Some authors have related age differences in reading ability with diminished working memory capacity, since older readers' working memory capacities are less than those of younger readers (e.g., Miller & Stine-Morrow, 1998; Stine-Morrow, Loveless, & Soederberg, 1995; Risse & Kliegl, 2011). These authors have also found that older adults appear to allocate more processing resources to the integration of new concepts as they are introduced in a text, whereas young adults tend to wait until the end of the sentence to integrate the new concepts. Miller & Stine-Morrow (1998) attributed this pattern to an attempt to compensate for age-related differences in working memory capacity.

A complementary, qualitative explanation for age differences in reading was suggested by Rayner et al. (Rayner et al., 2006, 2009, 2014), who argued that older readers might adopt some kind of specialized reading strategy to compensate for their slower reading and/or their age-related limitation in working memory capacity. For example, they might adopt a "riskier" reading strategy (Rayner et al., 2006; Rayner et al., 2009, 2014). Specifically, older readers might rely more heavily on partial visual information (perhaps from parafoveal vision), or they might rely on frequency and predictability information to effectively skip more words in the sentences. Given their extensive experience with reading text, they might be willing to make more guesses about what upcoming words in the text are likely to be, more so than younger readers. In this case, there would be qualitative differences between the eye movement behaviors of older and younger readers.

At this point, it is possible to highlight and synthetize the main explanations given in the literature and reduce them to two main hypotheses which attempt to explain age-related differences in eye movement patterns between young and old readers. On one hand, differences in eye movement patterns across age groups can be due to *changes produced by degenerative problems*. This consideration is supported by the fact that visual abilities decline with normal aging, and older adults experience a range of subtle visual deficits that could affect their resolution of the spatial frequency contents of words during reading (e.g., Elliott, Yang, & Whitaker, 1995; Owsley, 2011). It is also true that older adults show increases in the frequency and size of fixation variabilities compared to younger adults in ophthalmological assessments (e.g., Zaroff, Knutelska & Frumkes, 2003). Thus, eye movement studies should be useful in measuring changes that occur in the way people read as they age, begging the question of whether these changes are solely produced by aging or additionally accentuated by degenerative visual problems. For example, a progressive change in visual abilities occurs with normal aging and appears predominantly as a decline in sensitivity for detailed visual information (e.g., Elliott et al., 1995; Owsley, 2011). This loss of sensitivity to information supplied by higher spatial frequencies is widely attributed to a combination of optical changes and changes in neural transmission with increasing age, but the precise effects of these changes on older adults' reading abilities are unknown.

On the other hand, differences in eye movement patterns across age ranges can be due to the *use of different reading behaviors as compensatory strategies*. The data might reflect a supplementary or compensatory strategy that older readers use to maximize their reading speed despite age-related declines in visual processing—a so-called "risky" reading strategy (O'Regan, 1990). Older readers might make use of preceding context and partial parafoveal information to make hypotheses about upcoming text, leading them to make longer saccades and skip over information more often than younger adult readers, but also resulting in more regressions when their guesses are incorrect. This proposed guessing strategy is especially "risky" given that there is evidence from non-reading tasks that older readers are less effective at processing nonfoveal information (Ball, Beard, Roenker, Miller, & Griggs, 1988; Sekuler, Bennett, & Mamelak, 2000). In reading, this translates to a reduced perceptual span in older readers, which extends only about one word to the right of fixation (Rayner et al., 2009; but see Risse & Kliegl, 2011). Older readers are not only likely to make use of a smaller region of text on each fixation, but their perceptual spans are also more symmetric around the point of fixation, such that older readers rely less on the words to the right of fixation than young adult readers. Perhaps it is not surprising then, given their reduced processing of nonfoveal information and smaller perceptual spans, that older readers also show attenuated preview benefits from the word to the right of fixation (Rayner et al., 2010; but see Risse & Kliegl, 2011). In summary, older adults not only process information from a reduced perceptual span in any given fixation, but they also are limited in the amount of information that they can process from parafoveal vision. These results are often interpreted as signs that older adults have greater difficulty in processing visual inputs while reading, thus prompting the adoption of a “riskier” reading strategy in order to compensate for poorer text processing by attempting to determine word identities as early as possible on the basis of partial word information (e.g., Rayner et al., 2006, 2009). In addition, older adults probably make more use of world knowledge and top-down processes in reading than younger readers do. They have greater linguistic and world-knowledge that accrues from habitual engagement with text throughout adulthood, and such knowledge might serve as buffers against the effects of sensory decline in later years (e.g., Stine-Morrow et al., 2006). This hypothesis seems to be consistent with the evidence that despite some perceptual and working memory difficulties, older readers maintain a similar level of reading comprehension when compared with younger adult readers (e.g., Paterson et al., 2013a; Rayner et al., 2010).

Even though there are dozens of studies of eye movement differences between younger and older readers, until now no meta-analysis has been performed to synthesize the evidence for differences in reading eye movements between different age groups. It is necessary to highlight that it is out of scope of the present meta-analysis to solve the open issue and to offer evidence of any or both of the hypotheses described above, namely neural degenerative problems and the adoption of compensatory strategies. Thereby, the main objective of this study is to offer an integrative and quantitative review of these differences in reading eye movements between young and older adults, using meta-analytic techniques. Thus, the principal contribution of the present meta-analysis will be to provide important information on the stability and the homogeneity of age-related eye movement patterns across the literature, which would hopefully help to solve the controversy between degeneration and compensation hypotheses in the long term.

Method

Selection of studies

A search was conducted using a variety of methods. First, we searched the resources PsychInfo, PubMed, Medline, Web of Knowledge, and Google Scholar. The keywords for the search (both in English and Spanish) were all combinations among *eye movements / eye tracking*, *age differences / children / adults / younger adults / older adults, reading comprehension,* and *reading*. Second, we searched the relevant data bases of two university libraries (Universidad Autónoma de Madrid and University of Leiden) using the same search terms. Finally, we contacted the authors of the papers recovered via e-mail to ask for any new studies, papers in press, or other sources of additional data. These searches yielded a total of 62 documents, but the final sample of studies used here was composed of 19 papers, totaling 22 experiments.

The following were the inclusion and exclusion criteria (see Figure 1):

1. They report empirical data, not simulated data.
2. The stimuli employed for the eye movement tasks were in English or Spanish.
3. The experiments were performed in 1990 or later. Experiments had to have been published after 1990, in order to achieve reasonable homogeneity in the technology used to record eye movements.
4. The experimental participants differed in studies performed by the same authors.

5. They included eye movement measures analyzed in the present meta-analysis (see below).

6. The experimental stimuli were written text, and the analyses were done at the paragraph, sentence, or word level at a minimum (word level was included because we consider the ways in which people recognize individual words to be important for reading).

7. The authors reported sufficient statistical information to compute effect size indices: means and standard deviations, *t* tests, or *F* tests with one degree of freedom in the numerator.

8. They reported data from at least two different age groups, two of them being from our targeted age populations.

The two age groups employed in the comparisons were young adults (average of the mean ages, 21; range, 19 – 24), and old adults (average of the mean ages, 73 (range, 69 – 78). Table 1 specifies the studies finally included, along with the mean subject ages and their sample sizes.

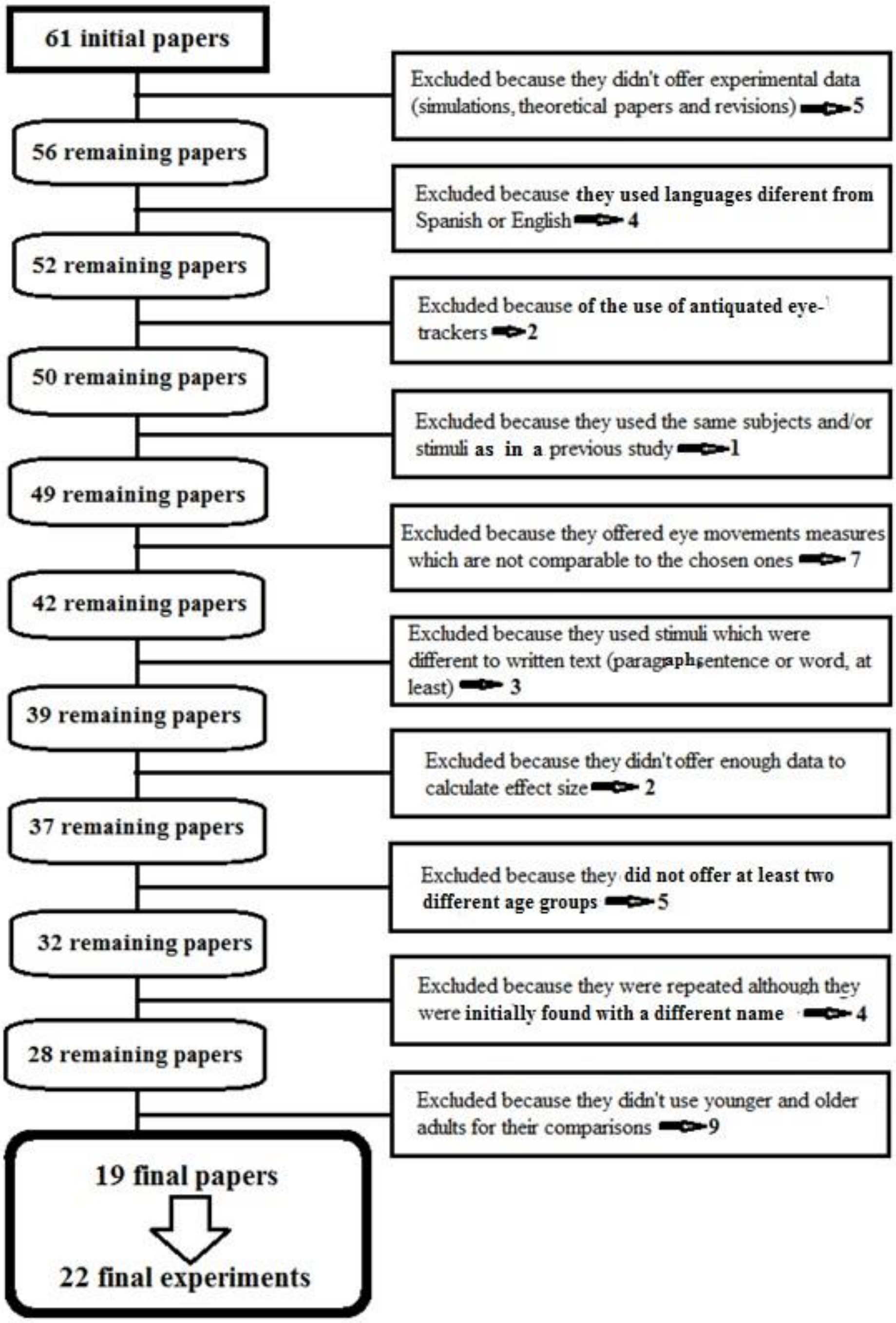

Figure 1: Flow chart (inclusion and exclusion criteria).

Table 1. Main descriptive statistics from the studies included in the meta-analysis.

Studies	Age_Y	Age_O	N_Y	N_O	FD	GD	MSRT	MNF	MNR	PSL
Kemper et al. (2004) E1	19.7	75.2	10	10	0.48	0.11				
Kemper et al. (2004) E2	19.75	75	16	16	0.00	-0.01				
Kliegl et al. (2004)	21.9	69.9	33	32	0.76	0.74				
Kemper & McDowd (2006)	19.8	75.3	35	49	0.50	0.32	0.54			
Rayner et al. (2006)	23.9	77.5	16	16	0.34	0.47	0.56	0.43	0.87	
Kemper & Liu (2007) E1	20.5	72.8	39	29	0.72	0.90				
Kemper & Liu (2007) E2	19.79	76.1	30	32	1.33	1.08				
Kemper et al. (2008)	22.2	73.4	24	24	0.84	1.37				
Rayner et al. (2009)	22.8	73.1	24	24	0.54		0.44	0.45	0.96	0.05
Rayner et al. (2010)	20.8	72.3	36	18		0.30				
Rayner et al. (2011)	21.8	72.3	32	32	0.12	0.31	0.83	1.02	0.56	
Risse & Kliegl (2011)	23	71	40	40		0.23				
Paterson et al. (2012) E1	22	69	16	16	2.65			-1.27	1.10	3.57
Paterson et al. (2012) E2	21	69	16	16	0.55			-0.97	0.00	5.52
McGowan et al. (2013)	19	72	16	16	1.72	0.16	2.50	1.81	5.35	3.98
Paterson et al. (2013)	21	73	12	12	1.71		0.57	0.57	2.96	5.55
Paterson et al. (2013b)	22	69	16	16	0.16	-0.69	2.82	2.97	5.20	5.13
Rayner et al. (2013)	21.3	77.8	16	8	2.03	1.58	2.13	1.11	5.14	3.50
Stites et al. (2013)	20.4	69.5	18	18	1.04	0.84				
Jordan et al. (2014)	21	69	16	16	3.70			-2.26		
Rayner et al. (2014)	21.3	77.6	16	16	3.45		2.49	1.26		1.29
McGowan et al. (2015)	19.9	72.5	15	15	2.54	1.01	3.28	1.76	5.72	5.19

The first columns show the average age and the sample size of the groups of old and young adults compared. The six columns to the right show the effect size (Cohen's d*) calculated for each measure obtained from each of the studies included in the meta-analysis (FD: Mean fixation duration. GD: Gaze duration. MSRT: Mean sentence Reading time. MNF: Mean number of fixations. MNR: Mean number of regressions. PSL: Progressive saccade length).*

Selection of eye movement measures and data extraction

First, the eye movement measures from each study were extracted, along with the definitions of the measures provided by the authors. Second, the eye movement measures were grouped into broad general categories. Subsequently, all authors' definitions were checked and, in agreement with a group of experts, the measures considered as homogeneous were pooled. Then, new definitions were agreed upon by the experts for any new groups of measures. Finally, based on all the above and the number of results available for each measure, we decided to keep six of the most relevant measures, as they also were the ones most frequently provided in the studies, and they offered a broad view of the eye movement data that usually characterize age group differences. Further, they all pertained to the general categorization of measures based on frequency or duration (measured in milliseconds). Regarding the text-level analysis, it is noteworthy that these eye movement measures were extracted in both single and multiple word levels, and were not averaged in any case. Each of the measures in the present study are shown in their original text level of analysis. It also is worth highlighting that 5 of the 22 experiments included in the present study employed single-word level analyses, and 17 reported data from multiple-word levels.

The proposed definitions for the six measures considered here were (see Hyönä, Lorch & Rinck, 2003):

1. Mean fixation duration (mean time): average length of all fixations on a word, phrase or target region, including re-fixations made at any time during reading, prioritizing the most complex structure (text > paragraph > sentence > word); measures at the character level were never included.

2. Gaze duration (mean time): average length of all fixations on a word, phrase or target region, before the eyes moved from it the first time, or before the gaze crossed the right bound or, failing that, if either of the above did not appear, the duration of the first fixation on a word, phrase or target region.

3. Mean sentence reading time (mean time): total length of the fixations on a target sentence that was syntactically and grammatically complete.

4. Mean number of fixations (mean frequency): average number of fixations in all the words, sentences, or target regions.

5. Mean number of regressions (mean frequency): average number of all regressions on all the words, sentences, or target regions, in which a regression was defined as any eye movement from a given point to an earlier point in the text (presumably read), being a word, sentence, or target region.

6. Progressive saccade length (mean frequency): average length of eye movements forward from the current point to a later point in the text, as measured by the number of character spaces between them. When available, the means, standard deviations and sample sizes were taken from the original report. If these descriptive measures were not available, the *t* or *F* statistics were used. In those cases, in which data from more than one group were available (either of different ages within each of the two comparison groups, or different experimental conditions), weighting formulas were employed to estimate single means and variances. When several experimental conditions were included in the design, our choice always included the control group, as it represented the condition closest to natural reading. When there was no control condition, we always included the condition with the more general task (closest to natural reading). In other cases, the results from several experimental conditions were averaged.

Effect size calculation and statistical analysis

Given the design of the experiments and the format of the statistics provided, our choice for an effect size measure was the standardized mean difference,

$$d = (\overline{X}_O - \overline{X}_Y) / \hat{S}_{pooled}$$

The standard deviations were obtained by pooling those from the samples. The order of the means in the numerator was due to the expectation of larger values for old adults than for young adults (longer times and higher frequencies), so that positive values were expected. That is, positive values of *d* reflected higher means in the older samples, whereas negative values reflected higher means in the younger samples. The *d* values were corrected for bias due to small sample sizes according to Hedges' (1981) formula (Borenstein, 2009; Botella & Sánchez-Meca, 2015). This correction is recommended in cases in which Cohen's formula uses the maximum likelihood estimator for the variance, which is biased with small sample sizes. The effect size values of each measure from each study are shown in the six columns on the right in Table 1.

Combined estimates of the effect sizes were obtained separately for each measure, weighting each estimate by the inverse variance method, $d_{\bullet} = \sum w_i \cdot d_i / \sum w_i$ (where $w_i = 1/\hat{S}_i^2$, and d_i is the effect size of each study; Borenstein, 2009; Borenstein, Hedges, Higgins & Rothstein, 2010). The heterogeneities of the estimates were analyzed by Q tests and I^2 indexes (Huedo-Medina, Sánchez-Meca, Marín-Martínez, & Botella, 2006). Statistical analyses assumed a random-effects model that is generally preferred because it is more conservative than a fixed-effect model, and allows generalizing conclusions beyond the specific set of studies analyzed (Borenstein et al., 2010; Hedges & Vevea, 1998; Raundenbusch, 2009). The method used to estimate between-study variability was the Hartung-Knapp-Sidik-Jonkman method for random-effects meta-analysis (IntHout, Ioannidis, & Borm, 2014). Calculations with this method were performed using R statistical software (version 3.3.2; R Core Team, 2016) with the Metafor package (Viechtbauer, 2010, 2010b) for the standardized mean effect size, the Q statistic, and the I^2 statistic estimates. An individual meta-analysis was performed with this method for each one of the eye movement measures reported in the present study.

Moderator variables

In order to analyze the heterogeneity between the results of the studies, moderator analyses were carried out for each of the eye movement measures. Five moderator variables were selected based on their potential explanatory role in the results of the analyzed studies and their availability in the presented data. The variables included: (1) the sampling rate in cycles per second of the eye-tracking apparatus (60Hz, 250Hz, 500Hz and 1000Hz), (2) the accuracy of the eye-tracking apparatus, based on the different sampling rates, but separating the highest rate from the others (i.e., classifying them as Medium for the cases from 60Hz to 500Hz and High for the cases with 1000Hz), (3) the difference between the mean ages the younger and older adults (ranging from 47 to 56.5), (4) the average age of the older adult groups (ranging from 69 to 77.8), and (5) the text level of analysis employed in the studies (one-word-level or multiple-word-level).

Multivariate meta-analysis approach

When multiple endpoints are analyzed independently, the probability of obtaining at least one significant result increases considerably. One way to avoid this problem is to use a conservative α value (e.g., 0.01 instead of 0.05). Another way consists of performing a multivariate combined analysis in which the endpoints are not independent, because the samples are the same (Gleser & Olkin, 2009a). We tried to do this with our data set, but it was not possible, as none of the studies offered values for all six measures. However, we employed a multivariate analysis for the combination that had a larger number of values available. Specifically, our database includes 14 studies that provided effect size estimates for the mean fixation duration and the gaze duration, simultaneously. We applied the Gleser & Olkin (2009) procedure to this subsample of studies; to do this, we used the sintaxis for R statistical software (version 3.3.2; R Core Team, 2016) proposed and developed by the same authors (Gleser & Olkin, 2009b), which uses functions from the Metafor package (Viechtbauer, 2010, 2010b).

Results

A summary of the results obtained for all measures is shown in Table 2. On one hand, all combined effect size estimates showed values ranging from .54 and 3.66. Within the six analyzed measures, five of them reached *p* values under .01, leading us to reject the null hypothesis of no age effect for those five measures. Mean number of fixations is the only measure for which the effect was not significant. The effect size had a positive sign in every case, indicating that the measures showed higher mean values for older adults than younger adults. Graphical displays of these results are shown in Figures 2, 3, 4, 5, 6 and 7 as forest plots for each of the six eye movement measures analyzed in the present study. On the other hand, all homogeneity tests showed values for the Q statistic with $p < .001$, leading us to reject the null hypothesis of homogeneity for all six cases. Thus, for all measures there was a margin of variability which could be explained by the presence of some moderator variable.

In the same way, all values of the I^2 statistic were over 62%, indicating that the heterogeneity was higher than random variability for the six cases. Again, this variability could be due to the effects of some moderator variables beyond random error. Specifically, for all cases, considering the categories proposed by Higgins and Green (2011), the heterogeneity should be assessed as *considerable* (>75%), with only one exception, gaze duration, which has *substantial* heterogeneity (65%).

Table 2: Combined estimates for the six eye movement measures with a random-effects model (significance tests with the Hartung-Knapp-Sidik-Jonkman method; IntHout, Ioannidis, & Borm, 2014)

Measure	*k*	*d*	95% CI	t (*p*)	*Q*(df)	I^2
FD	20	1.19	[0.69, 1.69]	5.00***	112.39(19)***	89%
GD	16	0.54	[0.25, 0.82]	3.95**	40.14(15)***	65%
MSRT	10	1.55	[0.75, 2.35]	4.38**	64.66(9)***	89%
MNF	12	0.56	[-0.36, 1.49]	1.35	124.75(11)***	93%
MNR	10	2.69	[1.03, 4.35]	3.66**	137.85(9)***	96%
PSL	9	3.66	[2.14, 5.18]	5.56***	142.54(8)***	92%

FD: Mean fixation duration. GD: Gaze duration. MSRT: Mean sentence Reading time. MNF: Mean number of fixations. MNR: Mean number of regressions. PSL: Progressive saccade length. k: Number of studies analyzed in each measure. d: Mean effect size.
****p<.001.*

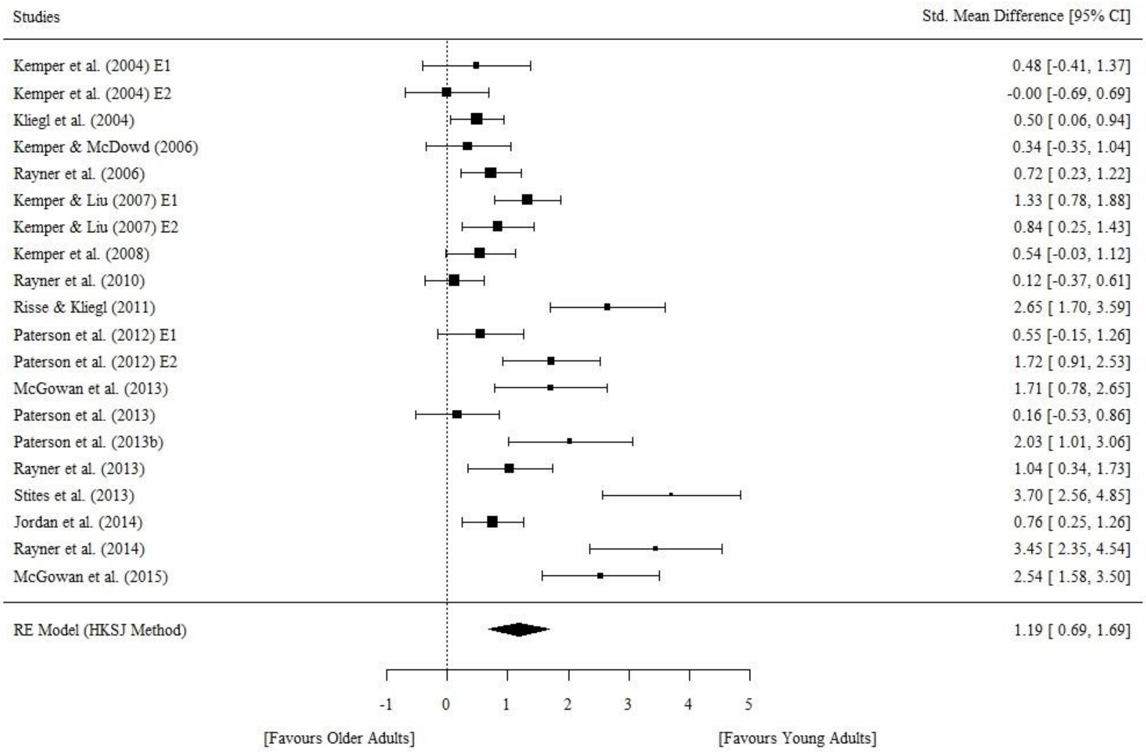

Figure 2: Forest plot of the mean effect sizes for the "Mean fixation duration" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

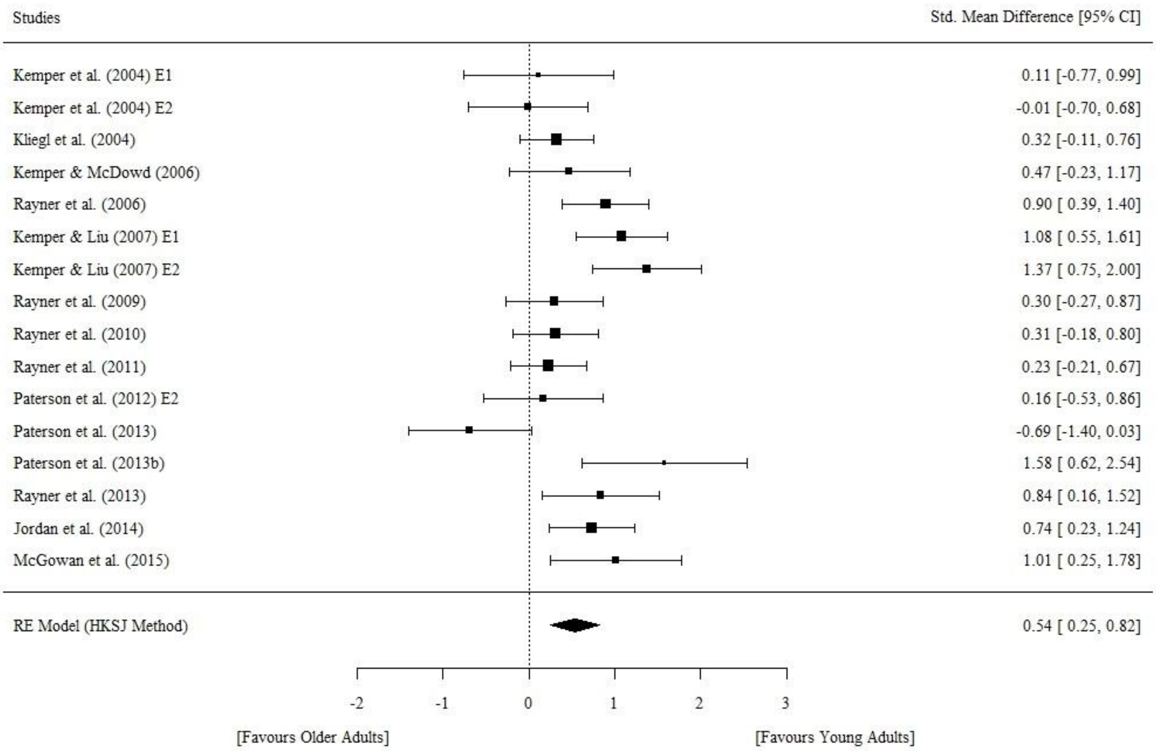

Figure 3: Forest plot of the mean effect sizes for the "Gaze duration" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

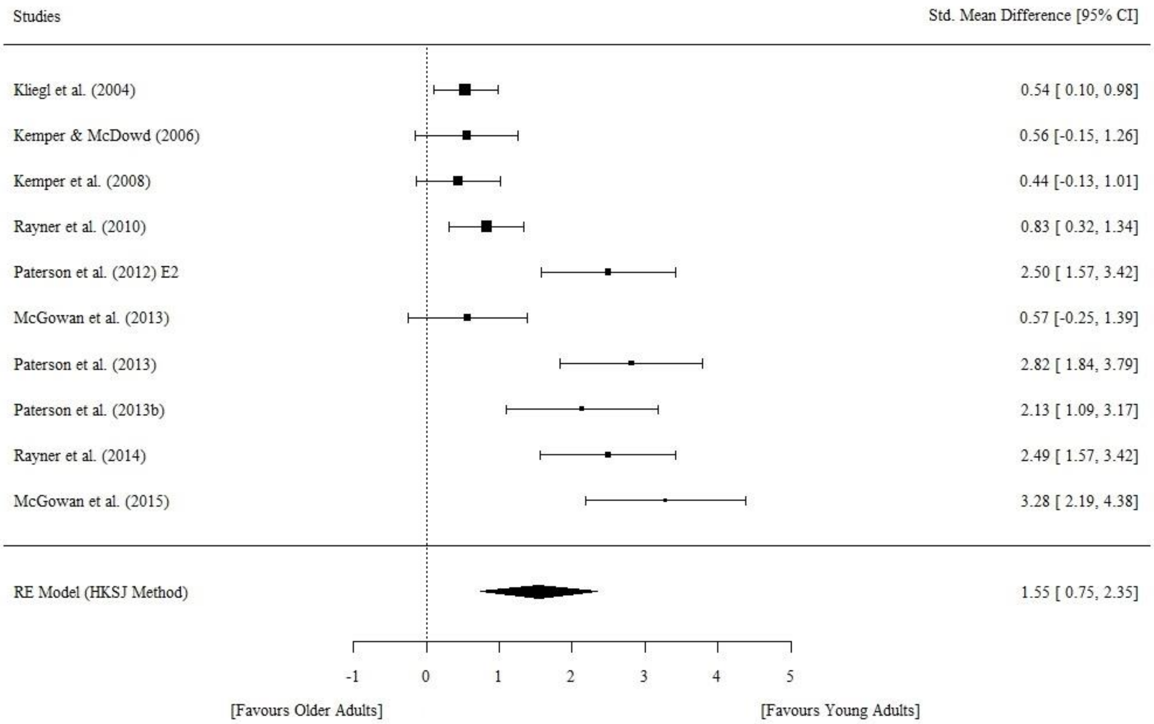

Figure 4: Forest plot of the mean effect sizes for the "Mean sentence Reading time" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

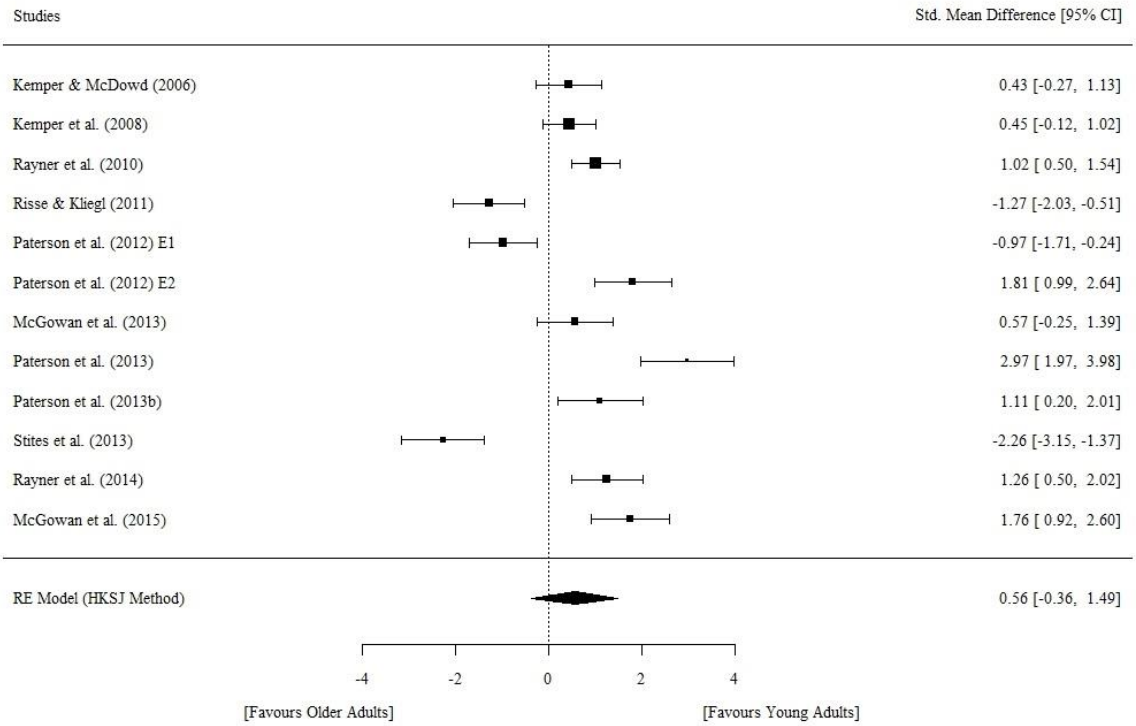

Figure 5: Forest plot of the mean effect sizes for the "Mean number of fixations" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

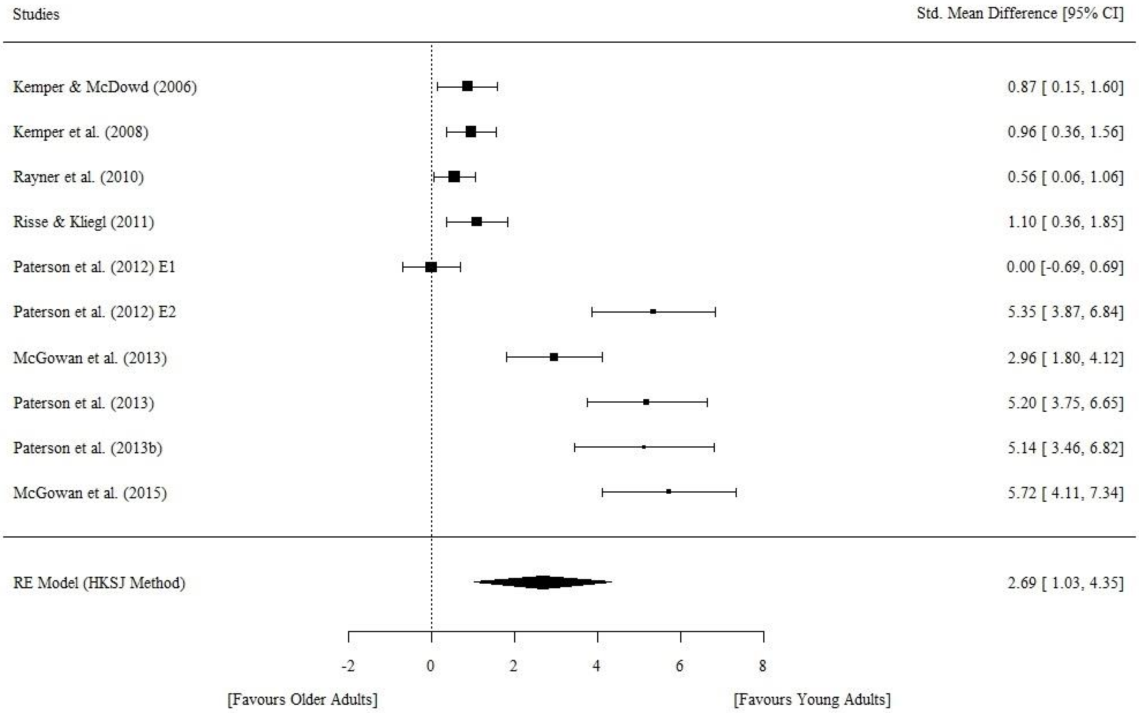

Figure 6: Forest plot of the mean effect sizes for the "Mean number of regressions" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

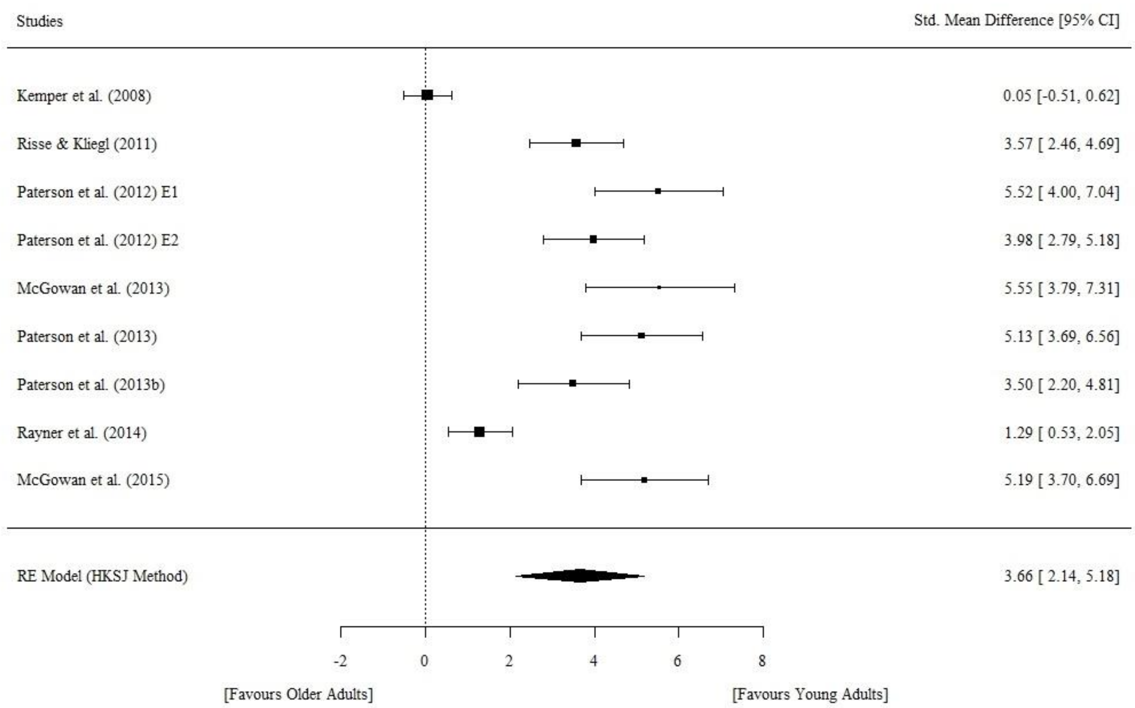

Figure 7: Forest plot of the mean effect sizes for the "Progressive saccade length" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

Moderator analyses

Moderator analyses showed non-significant effects ($p > .05$) of the variables of text levels of analysis employed in the studies, the age differences between the groups, and the average ages of the older adult group for each of the six eye movement measures. Non-significant effects were also found for the sampling rate in cycles per second of the eye-tracking apparatus and the subsequent accuracy of the eye-tracking apparatus variables for gaze duration, mean number of fixations and mean number of regressions ($p > .05$). In contrast to these results, statistically significant effects were found for two moderator variables; the sampling rate in cycles per second and the subsequent accuracy of the eye-tracking apparatus, for mean fixation duration, mean sentence reading time and progressive saccade length ($p < .05$). These results showed significant differences in the estimates made for eye movement measures in the analyzed studies, based on the accuracy of the eye-tracking apparatus employed. The direction of those effects are that a larger accuracy is associated to larger effect sizes for the mean fixation duration, the mean sentence reading time, and the progressive saccade length measures. The complete set of estimates is included in appendix A.

Multivariate analysis of effect size

In order to test the stability of the univariate meta-analytic results, we applied the Gleser and Olkin (2009) multivariate procedure to the selected subsample of 14 studies. The results we obtained are shown in Table 3. The procedure requires the correlations between the means of both measures, but none of the 14 studies gave us those data. For that reason, we imputed three correlation values: .2, .5 and .7. As shown in Table 3, the results were not significantly modified by the assumed correlation values. In addition, the conclusions did not change when analyzing data with a multivariate model instead of a univariate model. For the mean fixation duration variable, there was a relevant change in the estimate (1.15 for the univariate and 0.73 for the multivariate with r = .50). This discrepancy might be due to the fact that the multivariate analysis includes only 14 studies in which data for gaze duration were also offered.

Table 3: Synthesis of the multivariate analysis for both measures: "Mean fixation duration" and "Gaze duration" with 14 studies.

		HETEROGENEITY		TEST RESULTS			
CORRELATION	MEASURE	Q_w (df)	p-val	ES	SD	z-val	p-val
.2	FD	76.761 (26)	<.001	0.738	0.084	8.748	<.001
	GD			0.586	0.083	7.057	<.001
.5	FD	75.371 (26)	<.001	0.730	0.084	8.672	<.001
	GD			0.583	0.083	7.016	<.001
.7	FD	85.271 (26)	<.001	0.714	0.084	8.488	<.001
	GD			0.575	0.083	6.931	<.001

Fixed effect model. FD: Mean fixation duration. GD: Gaze duration.

Discussion

Based on the synthesis of the results from 22 experiments analyzed in the present study, we provide estimates of the age differences found in the main measures for assessing eye movements during reading (Table 2). This meta-analysis adds substantial information to what is available in qualitative reviews of the existing literature; namely, it shows the combined effect sizes for each of the eye movement measures analyzed in the present study, and it also has the potential to identify sources of heterogeneity observed in these effects across studies. There is a substantial variation in effect sizes across the 22 experiments included in the meta-analysis, and there are variables that moderate the effects observed. The findings of this meta-analysis are generally consistent with findings from previous studies, which compare the reading performance of young and older adults. In general, most of the studies that have compared skilled young adult readers and older adult readers led to the conclusion that older adults tend to read more slowly, make longer fixations, longer saccades, more regressions, and skip words more often (e.g., Kemper et al., 2004; Kliegl et al., 2004; McGowan, White, Jordan, & Paterson, 2013; Rayner et al., 2011). These conclusions are valid for nearly all the eye movement measures analyzed here, except for the “mean number of fixations” measure, whose combined estimate of the effect size did not reach a significant value. Therefore, we consider that these estimates can be informative, at least in order to confirm statistically the most common patterns observed in the literature, which have been described above. Thus, the present study offers an integrative vision of the state-of-the-art literature in the field. However, the current meta-analytic results do not allow us to discard either of the two main hypotheses for the observed aging effects; i.e., neuronal degenerative problems associated with aging and the potential development of compensatory strategies. Since we do not yet have the critical methods with which to derive contrastive predictions from these two positions, we cannot discard either of them. One of the conclusions of our meta-analysis is that it seems most reasonable at present to maintain the idea that both hypotheses are supportable and might well form credible, compatible and complementary explanations for the observed changes in eye movement behavior in reading that accompany advancing age.

It is assumed that some of the negative changes in visual processes produced by aging (e.g., neural degenerative problems) can be effectively reduced by activating other neurological or cognitive resources, as would be expected if compensatory reading strategies could be developed. Some authors have suggested that cognitive deficits in healthy older adults are largest for tasks that are highly dependent on executive control processes (such as working memory), because these processes are mediated by the prefrontal cortex (PFC), which is the region most disrupted by healthy aging (e.g., Cabeza, Grady, et al., 1997). Furthermore, older adults often present an hemispheric asymmetry reduction (see the HAROLD Model, Cabeza, 2002). This view, also known as the "frontal lobe hypothesis", rests on the assumption that both cognitive aging and specific cerebral losses go hand-in-hand in reducing executive control functions in elderly persons. Compared to young adults, older adults show reduced activity in some brain regions but increased activity in other brain regions. Cabeza, Anderson, Locantore & McIntosh (2002) describe the aging brain as a system that reorganizes its functions when necessary to compensate for certain losses due to reduction in neural capacities. However, greater activity is not always associated with better cognitive performance, and it is unclear whether increased activity in specific brain regions in older adults reflects compensatory strategies or merely attempts to deal with increasing task difficulty. It is also important to note that compensatory changes in the aging brain may not always reflect a net increase in brain activity, but rather an increase in functional connectivity. If older readers adopt a "riskier" reading strategy to compensate for their perceptual limitations in text processing by making more use of world knowledge and other top-down processes, this strategic change could be reflected in increased neural connectivity across brain regions. Although most functional neuroimaging studies of aging have focused on age effects on regional activity, there is evidence that functional connectivity is also modulated by aging, including increases in PFC connectivity (Cabeza et al., 2002). If age-related increases in PFC activity can be attributed to compensation processes, then it is possible that age-related increases in PFC connectivity could be also compensatory.

The current study can also help to address some issues in applied health-care settings and the design of multimedia resources for the elderly. For example, knowledge about the use of different reading strategies and different cognitive activities unique to older adults would be very relevant for health care systems. Clinicians working with older adults in a variety of settings could incorporate such knowledge in promoting better mental health in older adults. Older adults reporting cognitive declines (such as reading difficulties) should undergo cognitive testing. Checking what distinguishes normal versus degenerative visual changes will enable clinicians to provide reassurance to most older adults that they are experiencing changes as a normal part of the aging process. Anticipatory guidance for older adults should be expanded to focus on cognitive as well as physical health. Research confirms the benefits of initiating new cognitive health activities targeting specific cognitive deficiencies, and relevant activities are now readily available using text, computer, and gaming technologies (Vance, McNees, & Meneses, 2009). Applications of studies of cognitive aging that could be directed to better diagnosis, prognosis and care of elderly persons should be an important direction for future research given the gradual aging of our society.

Another applied setting that can be amenable to changes designed to go hand-and-glove with compensatory strategies for older readers are technological modifications of multimedia resources. Eye tracking tools might play an important role in the design of materials or procedures for information presentation, such as in adapting to individual differences or changes in reader's goals. For example, Kostons, Van Gog, & Paas (2009) used replays of participants' own eye movement records as a tool to help them self-assess their task performance. Similarly, reading tools such as e-books could be tuned to the natural eye movement patterns of individuals and different age groups. Although words are composed from a small set of letters, words are actually complex visual stimuli containing a variety of spatial frequencies ranging from low spatial frequencies that may be useful for determining the overall layout of text, including the size, shape, and location of words, to high spatial frequencies that may help to identify specific letter features (e.g., Allen, Smith, Lien, Kaut, & Canfield, 2009). Consequently, if changes in visual abilities associated with normal aging lead to changes in the functionality of various spatial frequencies when reading, younger and older adults might well differ in their use of the spatial frequency contents of text, and this may have important consequences for understanding adult age-related changes in reading performance. This conclusion has important technological applications in the design of a variety of text display devices, such as smartphones, tablets and e-books in order to make their contents accessible to older readers and those readers with specific visual and cognitive disabilities.

We are aware of some limitations of the present study. A major determinant of the validity of the meta-analysis is the sample size of studies that are included in the analysis. This determines which analyses can be carried out, as well as the quality of the results and the conclusions that can be extracted. In the present case the number of studies located was relatively small (especially for some of our measures). Research is limited because measuring differences in eye movement patterns across different age groups is a relatively recent research area, and it is difficult to tackle in that it requires very precise measurement instruments that are not always affordable or practical for use by investigative teams. Despite such sample limitations, it can be said with a good degree of certainty that the sample exhausts the present set of studies available on comparative research of eye movement patterns in young and elderly readers. However, the sample size was sufficient to satisfy the general requirements for the validity and reliability of the meta-analysis. Of course, given the correlational nature of meta-analysis our study cannot demonstrate any causal relationships. Nevertheless, we have reached conclusions consistent with the major body of previous literature, and we have achieved in provide relevant information on the stability and the homogeneity of age-related eye movement patterns in reading, offering an integrative vision of the state-of-the-art literature in the field.

Appendix A

Moderator analyses for the several eye movement measures employed.

Measure	Moderator	b	95% CI	t
FD	Hz	0.001	[0.00, 0.00]	2.73*
	Accuracy	1.19	[0.37, 2.01]	3.04**
	Age difference	0.006	[-0.15, 0.17]	0.08
	OA Average age	-0.01	[-0.19, 0.16]	-0.14
	Text level	-0.55	[-1.72, 0.61]	-0.99
GD	Hz	-0.00	[-0.00, 0.00]	-0.06
	Accuracy	0.05	[-0.59, 0.69]	0.17
	Age difference	0.05	[-0.05, 0.15]	1.11
	OA Average age	0.07	[-0.05, 0.18]	1.27
	Text level	0.26	[-0.58, 1.09]	0.66
MSRT	Hz	0.002	[0.00, 0.00]	3.11*
	Accuracy	1.65	[0.61, 2.70]	3.66**
	Age difference	-0.00	[-0.31, 0.31]	-0.02
	OA Average age	-0.09	[-0.40, 0.22]	-0.65
	Text level	1.31	[-0.19, 2.81]	2.01
MNF	Hz	-0.00	[-0.00, 0.00]	-0.03
	Accuracy	-0.09	[-2.33, 2.14]	-0.09
	Age difference	0.18	[-0.10, 0.46]	1.42
	OA Average age	0.14	[-0.14, 0.43]	1.14
	Text level	1.54	[-0.23, 3.30]	1.94
MNR	Hz	0.003	[-0.00, 0.00]	1.79
	Accuracy	2.73	[-0.42, 5.87]	2.00
	Age difference	0.30	[-0.27, 0.87]	1.21
	OA Average age	0.09	[-0.51, 0.68]	0.34
	Text level	1.69	[-1.95, 5.33]	1.07
PSL	Hz	0.008	[0.00, 0.01]	2.77*
	Accuracy	4.06	[0.59, 7.54]	2.77*
	Age difference	-0.16	[-0.62, 0.30]	-0.84
	OA Average age	-0.28	[-0.74, 0.17]	-1.48
	Text level	-1.07	[-5.00, 2.86]	-0.64

*FD: Mean fixation duration. GD: Gaze duration. MSRT: Mean sentence Reading time. MNF: Mean number of fixations. MNR: Mean number of regressions. PSL: Progressive saccade length. b: estimate of the effect. Hz: the sampling rate in cycles per second of the eye-tracking apparatus. Accuracy: Accuracy of the eye-tracking apparatus. Age difference: Age difference between age groups, older and young adults. OA Average age: average age of the older adult group. Text level: text level of analysis employed on the studies. ***p<.001.*

3.2. Specific relevance instructions promote selective reading strategies: Evidences from eye tracking and oral summaries

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Abstract

Background: The present study analyzed how relevance instructions affect eye movement patterns and the performance in a summary task of six expository texts. **Methods**: Forty-one undergraduate students participated in the experiment, half of them were instructed to make an oral summary of the main ideas focusing on the “why” question that appeared at the end of the first paragraph (specific relevance instruction), while the other half were instructed to make an oral summary of the main ideas of the text (general relevance instruction). **Results:** Eye movement patterns revealed that specific instructions promoted more and longer fixations and more regressions for relevant information than general instructions. A higher percentage of words in the summary task related to relevant information was recalled when readers received specific instructions. **Conclusions:** These findings suggest that relevance instructions influence how readers enact strategies to meet their reading goals and how these strategies are reflected on memory.

Keywords: relevance instructions, selective reading strategies, expository texts, eye movements, summary task.

Highlights

What is already known about this topic:

• A reading goal is formed on the basis of the reader's personal intentions and given intentions, such as a given reading perspective.

• Readers modulate their attention to task-relevant content in response to specific task instructions.

• There are strong evidences showing that eye tracking offers useful and accurate data about online processes during reading.

What this paper adds:

• The type of relevance instruction influences how readers enact strategies to meet their reading goals, and these strategies have an influence on memory.

• Readers who receive a specific relevance instruction show a strategic reading behavior, which is also reflected in the quality of their recall.

• Readers who adopt a selective strategy tend to use it in a consistent way across different texts and topics.

Implications for theory, policy or practice:

• There is a benefit in combining online and offline measures to examine the influence of relevance instructions on texts' strategic processing.

• The ability to distinguish relevant from irrelevant content in response to specific task instructions is an important instance of a competency that readers must develop in order to become efficient and effective as readers and learners.

• Assigning a comprehension perspective through relevance instructions should increase learning of perspective-relevant information from expository materials, such as textbooks.

Introduction

Comprehending instructional texts is essential in educational settings. The educational psychology literature is replete of research from the 1970s and 80s intended to improve students learning (e.g. Armbruster, 1984; Armbruster, Anderson, & Ostertag, 1987; Faw & Waller, 1976; Peeck, 1970; Kantor, Anderson & Armbruster, 1983; Hamaker, 1986; Hamilton, 1985). During this period, many studies promoted theoretical explanations of the effects of state variables (e.g., prior knowledge, criterion task, length of the instructional texts, adjunct questions, etc.) and process variables (e.g., allocation of attention, encoding strategies, selective processes, etc.) with their main focus being on general learning and selective learning from texts (e.g., Anderson, 1982; Armbruster, 1984; Hamaker, 1986; Hamilton, 1985).

A common approach cited in much of this literature was to analyze the effects of adjunct questions on prose learning (e.g., Anderson, & Biddle, 1975; Andre, 1979; Duchastel, 1983; Duchastel & Nungester, 1984; Hamaker, 1986; McGaw & Grotelueschen, 1972; O'Kon, 1988; Peeck, 1970; Reynolds & Anderson, 1982; Rickards, 1979). Adjunct questions are those that have been inserted into instructional texts to analyze their influence on what is learned. These adjunct questions, such as why questions, have generally produced a positive effect on learning, called a “forward effect” (Rickards, 1979). A forward effect consists of a change in the learner's processing strategy on subsequent text passages as guided by the type of question previously asked (O´Kon, 1988). Following Rickards (1979), the forward effect of adjunct questions can be classified into two types: a specific forward effect and a general forward effect. The specific forward effect is due to the learner's selective attention towards questioned material, whereas the general forward effect is due to an increase in the learner's overall attention to all information (Rickards, 1979). Each effect can produce different results in performance, depending on whether the test item was designed to measure learning of relevant or incidental material related to the question. More recently, Graesser & Lehman (2011) proposed the *focus assumption* model, supporting the specific forward effect by assuming that presenting a reader with a question will cause more attention to be devoted to question-relevant content than to content that does not pertain to the question. As a consequence, question-relevant information will be more likely to be encoded and remembered than incidental or irrelevant information.

Relevance instructions and their effects on text processing

Relevant information in a text can be determined from the perspective of the reader as well as from pertinence of specific instructions. For example, Sperber and Wilson (1986) define relevance as a function of the reader's goals or interest in reading a text; from the perspective of the reader, it is what makes the text content worth reading. It is important to recognize the "in situ" nature of relevance. Similarly, Lehman and Schraw (2002) define relevance as "the extent to which text segments are germane to the reader´s goal and purposes" (p.738), suggesting that reading goals and purposes are two factors that determine the relevance of text segments. Thus, relevance can change across readers and across different contexts for the same reader. Whatever the source of relevance for a given reader in a given situation, relevance has critical implications for text-processing. Readers can, in theory attend more fully (Kaakinen & Hyönä, 2005; McCrudden, Magliano, & Schraw, 2010) or more efficiently (McCrudden, Schraw, & Kambe, 2005) to relevant information, improving its comprehension and memory relative to less relevant information.

Despite the fact that most theories of comprehension do not account explicitly for text relevance, there has been considerable research on interventions that could be construed to be instances of relevance instructions (e.g., Kaakinen, Hyönä, & Keenan, 2003; Lorch, Klusewitz & Lorch, 1995; Lorch, Lorch, & Mogan, 1987; Narvaez, van den Broek & Ruiz, 1999). These studies often involve a pre-reading instructional set (e.g., read to summarize) or concurrent reading activity (e.g., answering adjunct questions) that directs the readers to specific dimensions of the text. This research has consistently demonstrated that the specification of a reading goal has overarching effects on how readers process texts. For instance, McCrudden and Schraw (2007) conducted an extensive literature review of research on the role of relevance instructions in text learning. They identified two main categories of relevance instructions that researchers have used individually or in combination, the general and specific relevance instructions (see McCrudden, Magliano, & Schraw, 2011, for a review).

General relevance instructions prompt readers to use a broad frame of reference while reading (e.g., read for comprehension; read to be able to summarize the main ideas of the text). Such purpose instructions provide readers with a general reason for reading that may influence the types of processing in which they engage, such as influences on the types of inferences made (van den Broek, Lorch, Linderholm, & Gustafson, 2001; van den Broek, Risden, Husebye-Hartmann, 1995). There are several empirical demonstrations that manipulations of general relevance instructions have systematic effects on readers' processing and memory for text (Kaakinen & Hyönä, 2007, 2008, 2011; Lorch et al., 1987; McCrudden et al., 2005; Narvaez et al., 1999; Rothkopf & Billington, 1979; van den Broek et al., 2001). There is also evidence suggesting that different mechanisms may underlie the effects of perspective instructions and purpose instructions. For readers possessing appropriate background knowledge, perspective instructions help them to distinguish particular content as being more or less relevant to the perspective. For example, in reading a description of the interior of a house from the perspective of a homebuyer, features such as room layout and size are relevant and should receive more attention; in reading the same text from the perspective of a burglar, the objects in the house are more relevant than the structural features of the house. Indeed, the two perspectives lead to systematic differences in what readers attend to while reading which, in turn, influences what they remember from the text (Kaakinen, Hyönä, & Keenan, 2002, 2003; Pichert & Anderson, 1977). In contrast, purpose instructions (e.g., read to comprehend, read for entertainment) appear to affect the types of processing in which readers engage. When reading to comprehend is compared to reading for entertainment, readers in the former case process text more carefully and construct a more coherent text representation (van den Broek et al., 2001; Lorch et al., 1995; Lorch, Lorch, & Klusewitz, 1993). Thus, whereas perspective instructions confer differential relevance on text content, purpose instructions seem to operate by affecting the relevance of different processes during reading.

Despite several findings that general relevance instructions affect how readers process texts, such instructional manipulations do not always produce unambiguous effects on text-processing (Graesser & Nakamura, 1982; Zwaan, Magliano, & Graesser, 1995). General instructions are often open to alternative interpretations; readers receiving the same instruction may develop different goals and use different strategies to reach those goals (McCrudden et al., 2010). For example, instructions to generate a summary of a text might lead to several different outcomes. Some readers might produce syntheses of the main ideas of the entire text; other readers might produce lists of explicit statements from the text; still other readers might include their opinions or evaluations of the text (León & Escudero, 2015).

Specific relevance instructions state reading goals that target a subset of text content as relevant. Specific relevance instructions are typically less ambiguous than general relevance instructions and therefore more consistently interpreted by readers. Specific relevance instructions include targeted text segments and elaborative question instructions (McCrudden et al., 2011). For example, a specific relevance instruction might be an elaborative "why" question intended to prompt readers to integrate specific segments across paragraphs and/or with prior knowledge (e.g., how did the Thames River become so contaminated?). Specific relevance instructions can take many forms, including pre-reading questions/objectives (i.e., presented to readers before they begin reading), pre-questions (i.e., inserted before and pertaining to upcoming segments), and post-questions (i.e., inserted after and pertaining to previous segments).

According to the *goal-focusing model* (McCrudden & Schraw, 2007; McCrudden et al., 2010), a reading goal is formed on the basis of the reader's personal intentions and given intentions, such as a given reading perspective. Text information is then processed in order to meet the reading goal with the result that relevant information is given priority over information that is not relevant to the reading goal. According to the framework of *perspective-driven text comprehension* (Kaakinen & Hyönä, 2008), perspective instructions activate relevant concepts in the reader's knowledge base. These concepts receive preferential status during text-processing. In sum, several researchers propose various mechanisms by which text content may be processed selectively depending upon the relevance of the content to the reader's goal. Selective processing seems more likely and appropriate in the context of specific relevance instructions than in the context of general relevance instructions (McCrudden et al., 2010).

These processing differences due to different types of relevance instructions should be reflected on the way readers inspect a text. There is empirical evidence from studies that analyze sentence reading times that readers modulate their attention to task-relevant content in response to specific task instructions. For example, competent adult readers pay relatively more attention to topic-introducing sentences (Lorch, Lorch, & Matthews, 1985, Lorch et al., 1987; Goldman & Saul, 1990) when they read to comprehend. Moreover, throughout the last years, the eye tracking methodology has been applied to investigate many different issues related to reading (e.g., Rayner, 1998), and this technology has been also used to investigate text-processing strategies (e.g., Blanchard & Iran-Nejad, 1987; Hyönä & Lorch, 2004; Hyönä, Lorch, & Kaakinen, 2002; Rothkopf, 1978; Vauras, Hyönä & Niemi, 1992; for individual differences in local reading strategies, see Olson, Kliegl, Davidson, & Foltz 1985).

The aim of this study was to analyze the effects of general and specific relevance instructions on the online processing, measured with eye movement data, and the offline processing, measured with an oral summary task, of question-relevant text information. In the present study participants read six different expository texts while their eye movements were tracked, and generated an oral summary related to the contents of the passage and also to a why question located at the end of the first paragraph after reading each text. Half of the participants received specific relevance instructions in order to summarize paying special attention to the why question, half received general relevance instructions in order to summarize the main contents of the texts. The why question was always located in every text at the end of the introductory paragraph in both conditions.

We applied eye tracking methods to analyze the influence of relevance instructions on the processing of question-relevant and irrelevant text sections. There are strong evidences that show that eye tracking is a useful method to examine online processes during reading, offering accurate data about the time-course of text processing (e.g., Hyönä et al., 2002; Kaakinen & Hyönä, 2005; Kaakinen, Hyönä, & Keenan, 2002). On the basis of Hyönä, Lorch & Rinck (2003), we computed several eye movement measures as the number and the duration of the fixations made in each paragraph, and also the number of regressions readers made from each paragraph to the initial paragraph of the texts. The eye tracking apparatus employed in the present investigation only allowed us to compute eye movement measures on a paragraph level. Even so, for the purposes of this study, paragraphs were the representation unit of interest, as they can provide information about inter-sentence coherence that are likely to have important influences on online processing of the relevant information of the texts (Hyönä et al., 2002) and also the possibility of examining systematic variations in processing between paragraphs.

Although there can be found a wide variety of research analyzing the effects of relevance instructions on the processing of expository texts, to our knowledge, little has been studied combining online measures as eye tracking methods, and offline measures as the quality of the recall from different expository texts. This can be understood as a methodological advance with respect to previous literature, as the combination of both kind of measures can be informative in order to have a better understanding about the reading processes and the subsequent product of the memory representation, and also about the reading strategies elicited by different types of reading instructions. Moreover, it can be helpful in order to link the consistency between these reading processes and the patterns in the recall, as it is expected to be a correlate between the reading patterns and the information included in the summaries. Thereby, a reader using a selective reading strategy, dedicating more and longer fixations to question-relevant than question-irrelevant text information, should be also expected to include more question-relevant than question-irrelevant information in the later recall task.

Purposeful reading can be described as a goal-directed activity in which readers interpret the signals of the context and the task to create their own mental representation, what will determine their reading goals and finally the kind of information they will extract from the text (Britt, Rouet, & Durik, 2017). Following the basis of the RESOLV framework proposed by the authors, we expected that readers who received specific relevance instructions should differentiate the question-relevant information in a more efficient way, being more selective in their processing. In this condition, the relevance signals given to the readers should elicit a more careful processing of the question-relevant text contents, which should be reflected in more and longer fixations on these regions, whereas the question-irrelevant paragraph should be more superficially processed. Besides, more regressions are expected to the introductory paragraph, which contains the question, from the question-relevant paragraphs, as possibly an attempt to build links between the question and the question-relevant information in the memory representation of the readers (Hyönä et al., 2003). As a consequence, this selective processing should be reflected in better recall of question-relevant than question-irrelevant information, compared to the condition in which participants received general relevance instructions. There are not specific relevance signals that focus participants in this condition on question-relevant information, although the why-question inserted within the text can also work as a more tenuous kind of relevance signal. Nonetheless, they are expected to distribute their attention more uniformly across the question-relevant and question-irrelevant paragraphs, and the content of both paragraphs should be represented in a more homogeneous way in their recall. In addition, we were also interested in analyze how consistently readers who used the selective processing strategy used it along the six experimental texts.

Method

Participants

Participants were 41 students (16 males; age range: 20–23 years) enrolled at the Autonomous University of Madrid, Spain. All participants had volunteered to participate in the experiments, and they received extra course credit as compensation. All of them were native speakers of Spanish (the language studied here), and had normal or corrected-to-normal vision. Additionally, all participants who took part in this study were from the same academic group and the same academic year. All of them were third-year psychology students and participated in the same laboratory conditions. All participants read the same six expository texts but they were randomly divided into two groups according to the reading instructions they received: 22 participants received specific relevance instructions and 19 participants received general relevance instructions. The duration of the experiment was same for both groups.

Apparatus

Eye movements were collected by an EyeTech™ Digital Systems VT2 infrared eye tracker, with two infrared light sources and an integrated infrared camera. The VT2 has two cameras mounted on a headband (one for each eye) including two infrared light-emitting diodes (LEDs) for illuminating each eye. The cameras sample pupil location and pupil size at the rate of 80Hz. Registration was binocular, and for cases that it not was possible, monocular. The camera was fixed under a 15-inch laptop computer on which stimuli were presented to each participant. Participants were also instructed to use a chin-and-forehead rest to stabilize their head positions during the test, positioned at about 60 cm from the eye tracker.

Materials

Eight expository texts were created for use as stimuli and two were used only for practice. Each text was approximately 200-250 words long (Spanish version) and included six different expository topics (Thames River pollution, Mediterranean diet, evolution of the suitcase, history of popcorn, urban growth, detective novel, insomnia, and the greenhouse effect). All of these texts were divided into three paragraphs. Each text began with a short introduction that finished always with a why question about the main topic. Each topic was developed in two subsequent paragraphs, one included relevant information to the question and the other one involved filler information that was coherent with the topic but unrelated to the question (see Table 1). The answer to each question (relevant information) was introduced in the second or third paragraph; the order of presentation of the relevant and irrelevant paragraph was counterbalanced across participants. For each text, both paragraphs were equated in length in the original Spanish version. Each text fit on a single computer screen (maximum of 14 lines). Lines within a paragraph were typed single space; two blank lines were inserted between paragraphs. Each text was presented for as long as the participant cared to view it.

Table 1. An example of one of the experimental texts.

The Thames River

For centuries, London has been exposing the Thames to high levels of contamination. In 1849 it was found that salmon, like the rest of the flora and fauna, had disappeared from the river. The water, though, was still used for human consumption, a fact which led to over 35,000 deaths from diphtheria epidemics between 1831 and 1866. **But how did the river become so contaminated?**

Because London was a large, heavily populated and industrialized city, the pollution dumped into the river was of a mixed nature. First, the Thames received huge amounts of untreated organic waste from the sewers of London. Second, industries produced chemical waste (such as hydrocarbons, synthetic detergents, phenols, cyanide) that changed the pH of the water. Both types of pollution completely extinguished any form of life in the river.

The contamination led Londoners to avoid the Thames in summer. Every viscous drop of water that passed carried the smell of two centuries of urban pollution. And beneath the surface, the river was dead. In more than 70 kilometers, the water contained almost no oxygen, and fish and other living creatures that inhabited the river had been eliminated long ago. Until the 80´s, the Thames was one of the most polluted rivers in the world.

Note: The question and relevant paragraph are presented in boldface in the table but were presented without boldface in the experiment.

Procedure

The settings and the context in which the experiment was conducted was the same for all participants. The study was conducted in a small laboratory room, and each participant was run individually. The lighting conditions were the same for all the participants. For each participant, the eye tracker was calibrated using a 16-point calibration before the first practice text and then recalibrated after every two texts. Participants receiving general relevant instructions were told: “You will read a set of short expository passages. We want you to read the passages carefully, understanding as much of the passage as possible. Later, after reading, you will make an oral summary about main ideas to see how well you understood what you read.” Participants receiving the specific relevance instructions were told: “You will read a set of short expository passages. We want you to read the passage carefully, focus on the question that appears at the end of the first paragraph, and understanding as much of the passage as possible to answer the question. Later, after reading, you will make an oral summary about the main ideas related to the question to see how well you understood what you read.” After participants indicated they had finished reading the relevance instructions, they read the two practice texts followed by the six experimental texts. After reading each text, participants completed an oral summary of the text according to their instructional condition. The text was not displayed during summarization. Participants were allowed to read every text at their own pace. After each text, participants were asked to provide a summary of the text orally, and all the responses were recorded with a digital voice recorder. Every recording was manually transcribed after the experiment. When the summary was completed for the final text, the participant was debriefed and dismissed. The entire procedure was completed in approximately 25 min.

Measures and score

Three paragraph-level eye movement measures (see Hyönä, Lorch & Rinck, 2003) were computed for each of the six texts for every participant. The *number of fixations* (frequency), which is the sum of all the fixations made in a paragraph. The total *number of regressions* reflects the number of times readers returned from each paragraph to the introductory paragraph that contains the question after the first reading of that paragraph. Regressions to the first paragraph are presumed to indicate checks by the reader of the relevance of a paragraph’s content to the to-be-answered question (Wiley & Rayner, 2000). The *total fixation durations* (measured in seconds) refers to the sum of all fixation times for each paragraph.

Oral summaries instead of written summaries were selected for several reasons. First, an oral summary is different from a verbatim recall, as it is a concise statement of the most important information in a text, more spontaneous and natural than a written summary, while being more sensitive to possible effects of type of instructions as well as to the use of selective processing (León & Escudero, 2015). Oral summaries could be also used concurrently with eye tracking measures. By contrast, written summaries are more elaborate because they require specific writing strategies (not only comprehension strategies), such as planning activities related to writing, introducing several possible re-elaborations, attention to grammatical correctness, and the requirement of much more time to produce. A methodological limitation can be also controlled using the oral summary task, as it can be applied immediately after reading the text and it does not require recalibrating the eye tracking device more than necessary, avoiding to interrupt the timing of the experiments.

The summaries were scored for the number of words that contained ideas and corresponded in a coherent manner with the information presented in the introductory paragraph, the number of words that corresponded with the relevant paragraph, and the number of words that corresponded with the irrelevant paragraph. Raters made a recount of the total number of words dedicated in the summaries to each paragraph. The criteria to decide which words corresponded to the information presented in one of the three paragraphs were the semantic relation of the contents of the oral summaries to the contents of the three paragraphs that conform the texts. One trained rater scored all summary protocols and a second rater scored 30 randomly selected summary protocols. Both raters were unaware of the instructional condition to which a participant was assigned when scoring protocols. Inter-rater reliability was high (96%, Cohen's Kappa = .83), so scores from the first rater were used in the analysis. Some examples of summaries generated by participants from both instruction condition groups are presented in Appendix B.

Results

Analyses of the eye movement data

The first set of analyses examined the results for the online measures to determine whether the type of relevance instruction affected how readers processed the relevant and irrelevant paragraphs during reading. Analyses of variance were conducted separately on the three eye movement measures. Each ANOVA had the same design: Relevance instructions (general and specific) was a between-Ss factor whereas paragraph type (relevant and irrelevant) and the order of presentation of the relevant paragraph (located in second or third paragraph) were manipulated within-Ss. Table 2 shows means and SDs for each condition. Tables for the information about the models for all the dependent measures are presented in Appendix A.

Table 2. Dependent online (number of fixations, regressions, and fixation duration), and offline (word count per paragraph) measures means and standard errors for each condition.

			Number of Fixations		*Number of Regressions*		*Fixation Duration*		*Word Count*	
Instruction	Paragraph	Order	Mean	SD	Mean	SD	Mean	SD	Mean	SD
General	Irrelevant	2nd P.	25.03	12.16	.79	.66	7.36	5.17	23.66	21.19
		3rd P.	29.37	12.28	.53	.59	8.38	3.64	22.49	22.69
	Relevant	2nd P.	26.75	12.70	.45	.70	7.73	4.09	46.17	23.74
		3rd P.	24.19	11.63	.70	.62	6.67	4.11	43.15	25.02
Specific	Irrelevant	2nd P.	19.85	13.96	.48	.36	5.85	4.92	2.09	7.72
		3rd P.	24.42	13.81	.38	.50	7.18	4.35	2.44	8.96
	Relevant	2nd P.	38.41	25.76	.89	1.18	11.51	8.31	38.45	19.49
		3rd P.	35.04	23.05	.90	.64	10.00	7.39	40.25	21.93

First, consider the results for *number of fixations.* If the effect of specific relevance instructions is to induce participants to be more selective in their processing of relevant content compared to general relevance instructions, we would expect to see relatively more fixations on the relevant paragraph than on the irrelevant paragraph in the specific relevance condition than in the general relevance condition. As Figure 1 illustrates, that is what was found. The interaction of paragraph type with instruction was significant; F (1, 39) = 14.4, MSE = 564.8; $p < .001$, $\eta^2 = .270$. As Figure 1 shows, there were many more fixations on the relevant paragraph than on the irrelevant paragraph when participants received specific relevance instructions, but there was no difference in numbers of fixations between the two paragraphs when participants received general relevance instructions. No other interactions were significant.

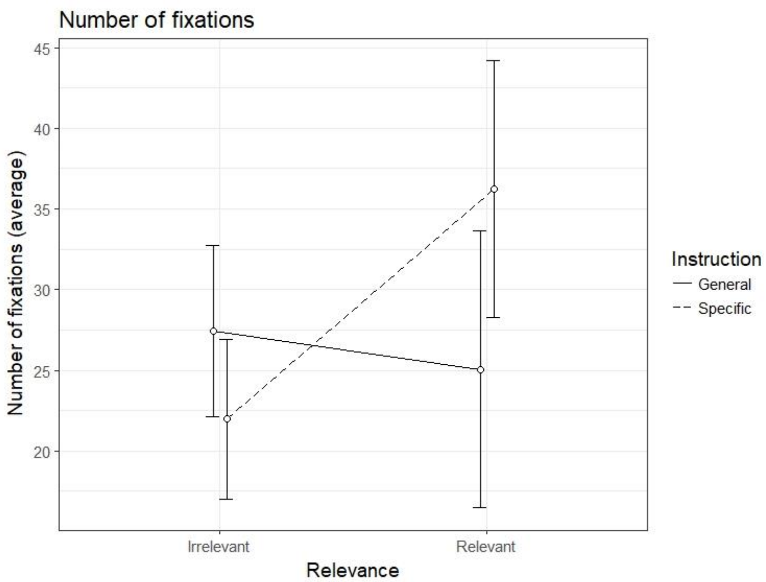

Figure 1. Number of fixations for the relevant and irrelevant paragraphs, as a function of instruction (General and Specific). Error bars represent 95% CI's.

Second, we analyzed *regressions* to the first paragraph which contains the question to see if the type of relevance instruction influenced processing associated with the question. Again, if specific relevance instructions caused readers to focus selectively on question-relevant information, we would predict more regressions from the relevant paragraph than from the irrelevant paragraph in the specific instructional condition, but not in the general instructional condition. Figure 2 confirms that this is what was observed. Again, paragraph type interacted with instructions; $F(1, 39) = 6.51$, $MSE = 1.44$, $p = .015$, $\eta^2 = .143$. There were many more regressions from the relevant paragraph than from the irrelevant paragraph when readers were under specific relevance instructions, but there was no effect of paragraph relevance when readers were under general relevance instructions. No other interactions were reliable.

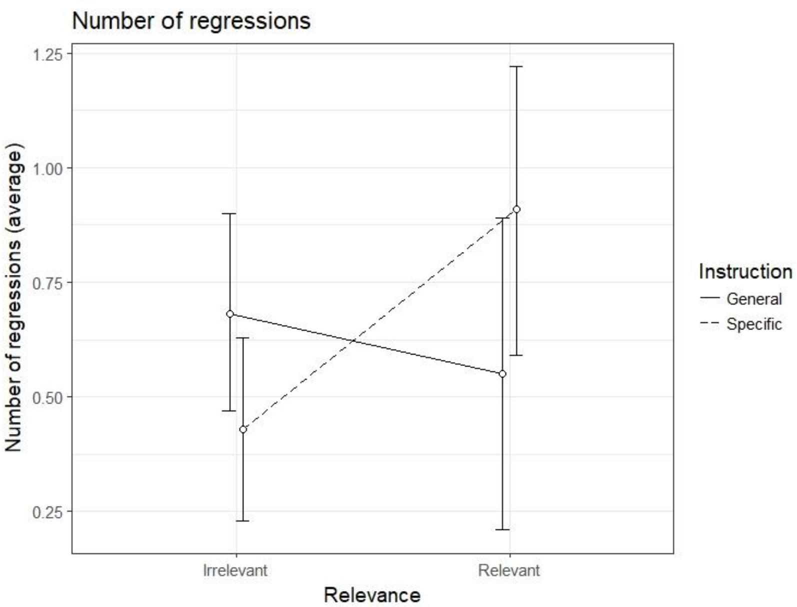

Figure 2. Number of regressions for the relevant and irrelevant paragraphs, as a function of instruction (General and Specific). Error bars represent 95% CI's.

Third, consider the results for *fixation durations.* If the effect of specific relevance instructions is to induce participants to devote more time to processing relevant content compared to general relevance instructions, we would expect to see longer total durations of fixations on the relevant paragraph than on the irrelevant paragraph in the specific relevance condition. As Figure 3 illustrates, that is what was found. The interaction of paragraph type with instruction was significant; $F(1, 39) = 12.76$, MSE = 19.28; $p = .001$, $\eta^2 = .247$. As Figure 3 shows, fixation durations were longer on the relevant paragraph compared to the irrelevant paragraph when participants received specific relevance instructions, but no differences were found between fixation durations data for the two paragraph types when participants received general relevance instructions. No other interactions were significant.

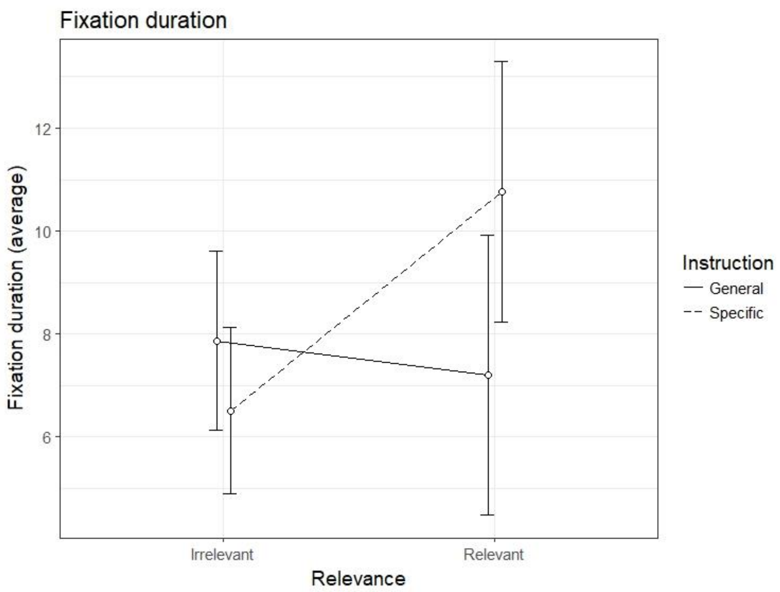

Figure 3. Fixation duration (in seconds) for the relevant and irrelevant paragraphs, as a function of instruction (General and Specific). Error bars represent 95% CI's.

In sum, the three measures of online processing were consistent in showing that participants receiving specific relevance instructions focused much more selectively on the content of the relevant paragraph than participants receiving general relevance instructions.

Analyses of the summaries

The oral summaries were scored for the number of words in each summary that were related to the introductory paragraph, the relevant paragraph and the irrelevant paragraph, respectively. These data were analyzed using an ANOVA in which the between-Ss factor was type of instruction (general and specific) and the within-Ss factors were type of paragraph (relevant and irrelevant) and the order of presentation of the relevant paragraph (located in second or third paragraph).

The key finding is again that type of paragraph interacted with instructions; $F(1, 38) = 18.46$, $MSE= 433.96$, $p < .001$, $\eta^2 = .327$. As can be seen in Table 2, participants in both conditions recalled similar amounts of content from the relevant paragraph in their summaries; however, participants receiving specific relevance instructions recalled much less content from the irrelevant paragraph than participants receiving general relevance instructions. Again, readers in the specific relevance condition focused selectively on the content of the relevant paragraph as was appropriate to their instructions. Figure 4 and Table 3 show the average proportions of words recalled for each type of text paragraph (introductory, relevant and irrelevant) and the type of instruction (general and specific).

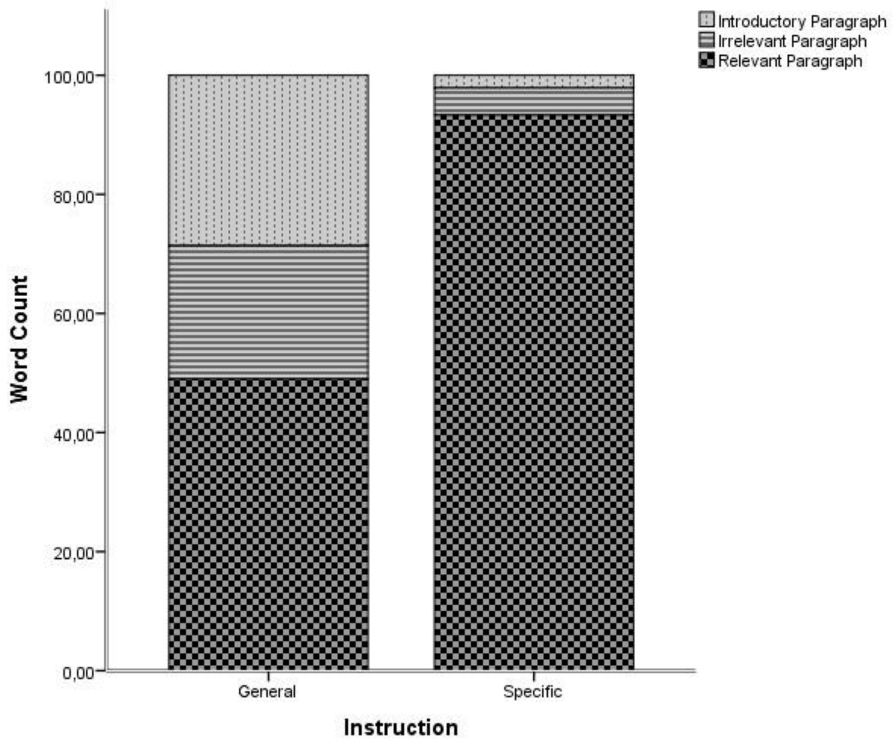

Figure 4. Mean proportion of words in oral summaries attributed to the introductory paragraph, the relevant paragraph and the irrelevant paragraph, respectively, as a function of instruction (General and Specific).

Table 3. Dependent offline measures (proportion account of words per paragraph, introductory, relevant and irrelevant) for each instruction condition (general, specific).

Instruction	% of Words (Introductory)	% of Words (Relevant)	% of Words (Irrelevant)
General	28.61%	48.97%	22.42%
Specific	2.13%	93.31%	4.57%

In addition, in order to analyze the consistency with which a reader applied a selective processing, we calculated the percentage of the words in their summaries originating from the relevant paragraph in each of the six texts. We classified processing of a text as selective if at least 80% of the words in the overall summary were recalled from the question-relevant paragraph. In the specific instruction condition, all of the readers consistently used a selective processing; specifically, 22.7% of the readers used a selective processing for five of the six texts and the great majority (77.3%) used a selective strategy for all the six texts. In the general instruction condition, the great majority of the readers used a selective processing for only two or fewer texts (i.e., 88.9%) and none of the readers used a selective processing for more than five of the texts.

Discussion

The purpose of the present study was to analyze how the type of relevance instruction affects readers' text processing, taking into account their eye movement patterns and the quality of their recall. Although there is considerable evidence about relevance instructions affect processing and memory outcomes, little is known about how general and specific relevance instructions affect readers in terms of the goals they set and the strategies they implement in order to match their performance on the task demands. This study adds several points of interest to what we already know about the topic from most of the previous research. First, we investigated whether the type of relevance instruction influenced the selectivity of readers' processing strategies. Second, we looked at the nature of readers' processing strategies across six different expository texts to assess how consistent they were in their use of a particular strategy. About the methodological aspects, online measures (eye movements) and offline measures (oral summaries) were combined in the same study in order to triangulate different types of data that are informative to analyze selective text processing.

Our results demonstrate that general and specific relevance instructions exert pervasive influences on the encoding strategies that skilled adult readers employ during reading, promoting two distinct types of reading processes: a selective processing strategy and a non-selective processing strategy. In the specific relevance instruction condition, readers activated a selective reading processing strategy in which they recognized the relevance of text segments early (i.e., relevant paragraphs), which then influenced how they allocated their fixations. Thus, they made more and longer fixations and more regressions, and spent more time processing relevant segments than irrelevant segments. Moreover, readers in the specific relevance condition also recalled proportionately more content from the relevant paragraph in the oral summary task. In contrast, readers in the general relevance condition used a non-selective processing strategy, characterized by no additional time and no increase in frequency of fixations and regressions on processing relevant segments over irrelevant segments. When summarizing, these readers recalled content equivalently across all paragraphs in the texts (i.e., they were not selective).

These data are consistent with most of the previous research about relevance instructions (e.g., Kaakinen et al., 2002, 2003; McCrudden and Schraw, 2007). Results of eye tracking studies of expository text comprehension show that readers spend more time processing perspective-relevant than perspective-irrelevant text information (e.g., Kaakinen et al., 2002). Also these results complement results of eye-tracking research generated within the *perspective-driven text comprehension framework* (Kaakinen & Hyönä, 2008). According to this framework, specific relevance instructions led readers to adopt the question stated in the first paragraph of a text as the focus for subsequent text-processing. This perspective caused activation of relevant concepts in the reader’s knowledge base which, in turn, facilitated processing of related content in the text. The results are also compatible with models that propose differences in processing of relevant and irrelevant information based on *goal-focusing* (McCrudden & Schraw, 2007), such as the adoption of *standards of relevance* (McCrudden et al., 2010), and the *focus assumption* (Graesser & Lehman, 2011). In general, these models predict that more attention will be devoted to relevant information within the question´s receptive field than information outside of the receptive field, with the result that relevant information is more likely to be encoded (Kaakinen & Hyönä, 2008).

Given the evidence that readers were much more selective overall in their text processing when given specific relevance instructions than when given general relevance instructions, we were interested in how consistent readers were in their use of a selective processing strategy in the present experiment. The pattern we found is that readers in the specific relevance condition were consistent in their use of a selective strategy. All of the readers in the specific relevance condition were classified as using a selective processing strategy on either five (22.7%) or all six (77.3%) of the experimental texts. Even so, the specific context of the experimental task and the adaptation of the participant to the procedure may also have an influence on this effect, but we think this is still remarkable given the variety of topics across the texts and also the counterbalance of the order of presentation of question-relevant and question-irrelevant paragraphs. This effect also suggests that readers' adoption of a selective strategy may not depend on their familiarity with the text topic.

This study also showed the value of combining online and offline measures in examining how relevance instructions influence reading text comprehension processes in the same research. Combining online and offline data allowed us to explain why some readers spent more or less time reading irrelevant information and why they provided divergent summaries of the texts. By using online and offline measures we were able to identify important differences in readers' goals and strategies that otherwise would have been hidden, such as in the results about their recall. For example, readers in the general relevance instruction condition used different reading strategies than readers in the specific relevant condition (selective versus non-selective reading processing), and they demonstrated different reading times, fixation frequencies, and more regressions to the question of interest, as well as different recall patterns. Readers within each experimental condition described using different strategies to meet their reading goals, which was corroborated by online and offline measures. Readers with specific goals spent less time reading irrelevant information and remembered less of this information, whereas readers with general goals spent more time reading irrelevant information and remembered more of it. These findings suggest that the type of relevance instruction influences how readers enact strategies to meet their reading goals and how strategies influence memory. Combined, these data demonstrate empirically that relevance instructions affect intentions and reading goals, which affect processing of information that is more or less relevant to goal attainment, which also affects memory.

Limitations

The eye tracking apparatus employed in the present investigation only allowed us to compute eye movement measures on a paragraph level. Even so, as results showed, we managed to obtain robust effects of the types of relevance instructions on text processing. Definitely, employing a more accurate eye tracking technology would permit to apply more precise analysis in order to evaluate the impact of relevance instructions on the eye movement patterns, having also more detailed information about what readers are actually doing while reading the relevant paragraph. Attending to that, we know that readers are spending more time reading the relevant paragraph than the irrelevant paragraph, but analyzing the eye movements with a more precise technology would allow us to have more information about more specific causes related to this pattern. For instance, it could be related to more time invested on the relevant paragraph during the firstpass reading, or it could be also due to a greater amount of re-readings on the relevant paragraph during the second pass reading. Nonetheless, analyzing eye movements on a paragraph level as in the present study has proven to show significantly the beneficial effect of relevance instructions on learning, as was demonstrated in previous research (McCrudden & Schraw, 2007; McCrudden et al., 2010) that it is closely related to strategic processing of texts.

Educational applications and future research

These findings have important implications for educational practices. Assigning a comprehension perspective through relevance instructions should increase learning of perspective-relevant information from expository materials, such as textbooks (Lehman & Schraw, 2002). An important future direction is to examine how relevance instructions affect readers with differing abilities and different levels of experience reading expository texts. For example, future research could be conducted to investigate how younger students use relevance instructions and adjunct questions together. Good readers can adapt their reading strategies to the requirements of different tasks, but it takes experience to learn how to make appropriate strategic adjustments to specific reading goals as well as to adjunct questions. The case of relevance instructions might be a fruitful area for early instruction in strategic processing because domains can probably be identified for which the distinction between relevant and irrelevant content is relatively easy for young readers. Moreover, there can be also beneficial educational implications of applying relevance instructions in specific cases of individuals with reading comprehension difficulties. As it has been widely exposed in previous research, reading comprehension is a high-level task, which involves many different cognitive processes and skills (Cain & Oakhill, 2004). Difficulties in reading comprehension might be related to a large variety of causes, both of the text and the context of the reading task, and also of the personal cognitive processes and abilities, what finally lead to a loss of proficiency in the reading task. As the results of the present study are pointing, to give readers with comprehension difficulties clear instructions and relevance cues (e.g., McCrudden et al., 2010) about the reading task, and specifically training them in the search for text relevance in early instructional stages (e.g., Britt et al., 2017) could be fruitful strategies in terms of helping these readers to develop clear and specific reading goals, which would finally lead them to be more focused and proficient in the reading tasks they are involved.

As was pointed above, future research should consider the application of relevance instructions to learning environments. Advancing research in this direction will require experimentation with a larger cross-section of participants, focused explorations of instructional prompts (i.e., those to instantiate different goals) to optimize learner comprehension, and considerations of the alignment of purpose and relevance with a teacher´s broader instructional plans. Along these lines, McCrudden et al. (2010) noted the importance of relevance instructions as a component of education´s overall adherence to instructional alignment. These authors highlighted the need to align learning objectives, learning activities, and measures of learning. The ability to distinguish relevant from irrelevant content in response to specific task instructions is an important instance of a competency that readers must develop in order to become efficient and effective as readers and learners.

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Appendix A

Information about the models for all the dependent measures.

1. Number of fixations

Between-Ss				
	F (df)	**MSE**	***p***	η^2
Intercept	181.93 (1,39)	126824.19	<.001	.82
Instruction	.56 (1,39)	390.12	>.05	.01

Within-Ss				
	F (df)	**MSE**	***p***	η^2
Order	.34 (1,39)	22.66	>.05	.01
Order*Instruction	.01 (1,39)	.84	>.05	.00
Paragraph	8.96 (1,39)	1686.46	<.01	.19
Paragraph*Instruction	14.41 (1,39)	2712.83	<.001	.27
Order*Paragraph	3.24 (1,39)	561.73	>.05	.08
Order*Paragraph*Instruction	.02 (1,39)	2.81	>.05	.00

2. Number of regressions

Between-Ss				
	F (df)	**MSE**	***p***	η^2
Intercept	66.71 (1,39)	66.71	<.001	.64
Instruction	.10 (1,39)	.09	>.05	.00

Within-Ss				
	F (df)	**MSE**	***p***	η^2
Order	.15 (1,39)	.03	>.05	.00
Order*Instruction	.09 (1,39)	.02	>.05	.00
Paragraph	3.16 (1,39)	1.52	>.05	.08
Paragraph*Instruction	6.51 (1,39)	3.12	<.05	.14
Order*Paragraph	3.26 (1,39)	.98	>.05	.08
Order*Paragraph*Instruction	1.38 (1,39)	.41	>.05	.03

3. Fixation duration

Between-Ss				
	F (df)	**MSE**	***p***	**η^2**
Intercept	136.94 (1,39)	10660.96	<.001	.78
Instruction	.63 (1,39)	49.24	>.05	.02

Within-Ss				
	F (df)	**MSE**	***p***	**η^2**
Order	.02 (1,39)	.12	>.05	.00
Order*Instruction	.01 (1,39)	.05	>.05	.00
Paragraph	6.77 (1,39)	130.43	<.05	.15
Paragraph*Instruction	12.77 (1,39)	246.09	<.001	.25
Order*Paragraph	3.24 (1,39)	61.29	>.05	.08
Order*Paragraph*Instruction	.08 (1,39)	1.50	>.05	.00

4. Word count

Between-Ss				
	F (df)	**MSE**	***p***	**η^2**
Intercept	212.34 (1,38)	116691.03	<.001	.85
Instruction	11.94 (1,38)	6559.92	<.001	.24

Within-Ss				
	F (df)	**MSE**	***p***	**η^2**
Order	.18 (1,38)	17.96	>.05	.01
Order*Instruction	.48 (1,38)	47.39	>.05	.01
Paragraph	220.80 (1,38)	31940.00	<.001	.85
Paragraph*Instruction	18.46 (1,38)	2670.76	<.001	.33
Order*Paragraph	.77 (1,38)	82.18	>.05	.02
Order*Paragraph*Instruction	1.18 (1,38)	125.90	>.05	.03

Appendix B

Some examples of summaries generated by participants from both instruction condition groups (translated into English from the original Spanish versions, also included).

Specific relevance instruction

"Dos tipos de contaminación produjeron la contaminación del Támesis: primero, la contaminación producida por los residuos orgánicos de las personas que vivían en Londres, ya que no había filtro, no se trataban debidamente e iban directos al río, y además, los residuos químicos que producían las fábricas de la época".

"Two kinds of pollution became the river contamination: first, pollution produced by the organic waste of people who lived in London, because there were not any kind of filter, and that waste was not properly treated and was directly thrown to the river. Besides, chemical waste produced by factories of that period".

"El Támesis se contaminó por dos razones: una por los residuos orgánicos que vertía la ciudad de Londres sobre él, ya que no existían sistemas de depuración, y otra los residuos químicos que vertían las fábricas y las industrias".

"The Thames became contaminated because of two reasons: on the one hand for the organic waste that the city of London poured over the river, as there were no purification systems, and on the other hand due to the chemical waste poured by factories".

General relevance instruction

"El texto habla del Támesis y de la gran contaminación que afectó Londres durante siglos. Fue a principios del S. XIX cuando se notó que había desaparecido mucho de la fauna y flora del río, porque estaba prácticamente contaminado por completo. Esto era porque al Támesis se vertían todos los residuos orgánicos que no tenían ningún tipo de tratamiento y también residuos tóxicos de las fábricas de la ciudad. Durante mucho tiempo, el río estuvo prácticamente muerto, no había apenas fauna y los ciudadanos tendían a evitarlo. El Támesis fue uno de los ríos más contaminados del mundo hasta los años 80".

"The text is about the Thames and the great pollution which affected London during centuries. In the beginning of the XIX century, it was noticed that flora and fauna had disappeared, because the river was completely polluted. That was produced because both, all the organic waste, which was not treated in any way, and also the toxic waste from factories of the city, were poured to the river. For a long time, the river was practically dead, there were barely no fauna and citizens tended to avoid it. The Thames was one of the most polluted rivers in the world since the 80's years".

"El Támesis ha sido uno de los ríos más contaminados. En 1849 se descubrió que todo el salmón que tenía había desaparecido a causa de la contaminación. Las causas de la contaminación básicamente eran dos: los residuos orgánicos que provenían de los desagües de Londres y una segunda que eran los componentes químicos que vertían las fábricas de Londres. Esto hacía que los ciudadanos no quisieran pasear por las orillas del río, porque olía mal y apenas había oxígeno, lo que provocaba que no hubiera ni fauna ni flora".

"The Thames has been one of the most polluted rivers. In 1849, was discovered that all the salmon disappeared because of the pollution. The causes of the pollution were basically two: the organic waste that came from sewers of London and the chemical components that were poured by factories in London. That made citizens did not want to walk near the shores of the river, because of the bad smell and also because there was no oxygen, which produced the absence of fauna and flora".

3.3. Impact of elaborative interrogation instructions on the processing of expository texts: An eye movement study

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Abstract

The present study examined how "why" questions presented in the beginning of a text influence expository text reading. Eye movements of 54 college students were recorded while they read expository texts with the purpose of summarizing and answering "why" questions, inserted either in the beginning of the texts or presented after reading. The passages contained an introductory paragraph (including the question), a paragraph with question-relevant information, and a paragraph with question-irrelevant information that was still topic-relevant. Participants produced a summary of each text after reading. Presenting the question in the beginning of text induced shorter firstpass fixation times in irrelevant paragraphs, longer look-back reading times in relevant paragraphs, more frequent lookbacks from the relevant paragraphs to the beginning of the text, and increased the recall of question-relevant information. These results suggest that elaborative interrogation, namely presenting a why question embedded in the beginning of text, improves strategic reading behavior.

Keywords: eye tracking, reading comprehension, elaborative interrogation, "why" questions, relevance.

Introduction

Instructing readers to ask and answer questions during the course of reading is an efficient way to improve comprehension and learning from text (e.g., Graesser & Lehman, 2011; León & Carretero, 1992). Especially answering "why?" questions, which typically require a synthesis of text information and prior knowledge, are likely to enhance comprehension that goes beyond merely encoding the text information at the "surface" or propositional level (e.g., Graesser, 2007). Reading in order to answer questions that require elaboration of the text information has been called *elaborative interrogation*, and its effectiveness in improving memory and comprehension of text has been demonstrated in a number of studies (e.g., Callender & McDaniel, 2007; Dornisch & Sperling, 2006; Kahl & Woloshyn, 1994; Martin & Pressley, 1991; McDaniel & Donnelly, 1996; Ozgungor & Guthrie, 2004; Pressley, McDaniel, Turnure, Wood & Ahmad, 1987; Seifert, 1993; Ramsay, Sperling & Dornisch, 2010; Smith, Holliday & Austin, 2010; Takaki, 2012; Willoughby, Waller, Wood & MacKinnon, 1993; Woloshyn, Paivio & Pressley, 1994; Woloshyn & Stockley, 1995; Woloshyn, Willoughby, Wood & Pressley, 1990; Wood, Pressley & Winne, 1990). An example of the usefulness of the method in an educational setting is a study by Smith et al. (2010), which demonstrated that biology students who were instructed to answer "why" questions while they were studying textbook materials clearly outperformed students who only reread the text materials in a subsequent comprehension test.

Previous studies have mostly examined the impact of elaborative interrogation on the learning outcomes, such as memory for facts (e.g., Seifert, 1993; Wood et al., 1990), inference-making (e.g., León & Escudero, 2017; McDaniel & Donnelly, 1996), and the quality of the mental representation constructed of the text information (e.g., León & Carretero, 1995; Ozgungor & Guthrie, 2004). In a study by Wood et al. (1990, Experiment 2), children who were generating answers to "why" questions while reading showed better recall of the facts presented in passages than readers who were presented with the elaborative information in the text or who were imagining the situation presented in the factual sentences. Also Seifert (1993) found that readers who were presented with a why question in a passage and instructed to answer that question after reading, showed enhanced memory of the main ideas presented in the text. In addition to improving memory for facts presented in text, interrogative elaboration has also been shown to improve inference-making (McDaniel & Donnelly, 1996), and to enhance the coherence of the mental representation constructed of the text information (León & Carretero, 1995; Ozgungor & Guthrie, 2004). McDaniel and Donnelly (1996) suggested that elaborative interrogation enhances construction of a comprehensive situation model of the text contents, which means that readers go beyond the information presented in the text and make inferences in order to form a good mental model of the information presented in text (Kintsch, 1998).

While there is ample evidence suggesting that elaborative interrogation improves learning outcomes, relatively little is known about how why questions influence the moment-to-moment processes occurring during the course of reading. Questions may guide readers to look for information that is important for answering the question (McCrudden & Schraw, 2007). Readers will need to evaluate the relevance of text segments with respect to the question, and to integrate the relevant information into a single, coherent answer (Graesser & Lehman, 2011). This may require readers to invest extra attention on question-relevant text segments. Indeed, when questions target specific information in text, readers spend longer time viewing question-relevant than irrelevant text segments (e.g., Lapan & Reynolds, 1994; Reynolds, Standiford & Anderson, 1979). In other words, "why" questions can be assumed to induce a selective attention strategy, in which readers pay more attention – and spend longer processing time – on question-relevant than irrelevant text information, which results in improved learning of question-relevant information (e.g., McCrudden, Magliano & Schraw, 2010).

Answering a why question often requires building links between different text segments (e.g., Graesser, 2007), and this may be reflected in how readers inspect the text. For example, a reader may decide to reread parts of text that are crucial in building a coherent memory representation of text (see e.g., Hyönä, Lorch & Kaakinen, 2002). In the present study, we used eye tracking to examine how a why question presented in the beginning of a passage influences the subsequent processing of question-relevant and irrelevant text segments. Eye tracking has proven to be a useful method for examining the moment-to-moment processes occurring during the course of reading (e.g., Rayner, 1998). In a typical eye tracking experiment, readers can freely inspect the text at their own pace, and it is possible to separate eye movements that were made during the first-pass reading of a text segment from later look-backs to that segment, providing a detailed analysis of the time-course of text processing (see e.g., Hyönä, Lorch & Rinck, 2003). Especially look-backs – i.e. returning to a text segment from subsequent parts of text – have been shown to be important in comprehension (Hyönä et al., 2002; Kaakinen & Hyönä, 2005; Schotter, Tran & Rayner, 2014).

To our knowledge, there are only few studies that have utilized eye tracking to study the impact of elaborative interrogation on the readers' viewing patterns (Kaakinen, Lehtola & Paattilammi, 2015; Wiley, Goldman, Graesser, Sanchez, Asch & Hemmerich, 2010). Wiley and colleagues (2010) showed that rereading was an elementary aspect of a "smart" processing strategy induced by elaborative interrogation instructions. They examined how readers inspected websites that were rated either as reliable or less-reliable sources of information, and found that readers who were instructed to produce explanatory arguments engaged in more rereading of trustworthy sites. In a recent eyetracking study by Kaakinen, Lehtola, and Paattilammi (2015), readers were asked to read short expository texts that either had a why question (e.g. Why is recycling important?) or a statement (e.g., Recycling is important) as a title. The texts did not contain specific question-relevant segments, as answering the why question required the readers to integrate different pieces of text information together. Adult readers demonstrated faster first-pass reading times, and higher probability of look-backs within the passage when the title was a why question than when it was a statement. These results suggest that why questions facilitate initial reading of the passage, and increase integrative processing of the text contents. However, both of these previous studies provide information on how elaborative interrogation and especially why questions impact processing of text on a global level. It remains unclear what kind of specific processing strategies why questions may induce.

Previous studies examining the influence of a specific reading goal (e.g., “read this text describing different countries so that you can afterwards tell facts about Honduras”) on eye movements during reading suggest that readers adopt a selective processing strategy (McCrudden, Magliano & Schraw, 2010): they spend longer time on goal-relevant than irrelevant text segments already during first-pass reading and they also return more to task-relevant segments from subsequent parts of text (e.g., Kaakinen & Hyönä, 2007; Kaakinen, Hyönä & Keenan, 2002). This extra time invested in relevant text segments seems to be related to increased effort to rehearse or maintain task-relevant information in memory (Kaakinen & Hyönä, 2005). Indeed, after reading readers show clearly better recall of task-relevant than irrelevant text information (e.g. Kaakinen & Hyönä, 2007; Kaakinen et al., 2002). Similar results have been reported for the impact of prereading questions on processing and memory for text (Lewis & Mensink, 2012). When given a set of prereading questions, readers spent longer time rereading question-relevant sentences both during first-pass and during later look-backs. In a free recall task, readers showed higher recall rates for question-relevant text information. However, giving readers a specific reading goal or a set of prereading questions that instructs them to concentrate on specific type of information in the text does not necessarily enhance elaborative processing in the same way as interrogative elaboration instructions do.

The goal of the present study was to examine the processing strategies induced by "why" questions that are presented in the beginning of a passage. In this study, participants read six different expository texts while their eye movements were tracked, and answered a why question related to the contents of the passage after reading. Half of the participants read texts in which a why question was presented in the beginning of the passage, half received the question only after reading. We expected that a question presented in the beginning of a passage triggers a selective attention strategy (e.g., McCrudden, Magliano & Schraw, 2010), in which readers assess the relevance of each text segment with respect to the question, and invest extra attention -- as reflected in increased rereading and looking back -- especially to question-relevant text segments. This should result in better recall of question-relevant text information in comparison to the condition in which the question is presented only after reading.

Method

Participants

Participants were fifty-four psychology students (21 male; age range: 20–23 years) enrolled at a Spanish public university. All participants had volunteered to participate in the experiments, and they received extra course credit as a compensation. All participants were native speakers of Spanish (the language studied here), and had normal or corrected-to-normal vision.

Apparatus

Eye movements were recorded with an EyeTech™ Digital Systems VT2 infrared eye tracker. The VT2 has two infrared light sources and an integrated infrared camera. It connects via USB to a Windows computer and captures the eye gaze location (x, y coordinates) at a sampling rate of 80Hz. Registration was binocular, and for cases that it not was possible, monocular. The camera was fixed under a 15-inch laptop computer on which stimuli were presented to each participant. The laptop screen was placed 60 cm from the participant, and it used a 100 Hz refresh rate and 1366 x 768 resolution. Participants were instructed to use a chin-and-forehead rest to stabilize the head position during the test. Following the calibration standards of the manufacturer, the 96% of the calibrations made for this study were considered “excellent” and the 4% “very good”.

Materials

Six expository texts were used as stimuli, and there were two additional texts for practice. Texts were 200-250 words long and they introduced six different expository topics (the Thames, Mediterranean diet, the suitcase evolution, popcorn history, urban growth, detective novel, insomnia and the greenhouse effect). Each text began with a short introduction, followed by two paragraphs that developed the topic of the text (an example text is presented in the Appendix A). There were two versions of each text: in one version, a why question was presented at the end of the introductory paragraph; in the other version, the question was omitted from the introductory paragraph and presented after the text. The two paragraphs that followed the introduction contained either information that was relevant to answering the why question (i.e., relevant paragraph), or information that was coherent with the topic of the passage but irrelevant for answering the question (i.e., irrelevant paragraph). The order of the relevant and irrelevant paragraphs was counterbalanced across texts. Each text was presented on one screen, maximum of 20 lines of text per screen.

Relevance ratings

A norming study was conducted in order to verify that particular paragraphs are more relevant than others with respect to the task instructions given to the participants. Fifteen participants (3^{rd} year psychology students) who did not participate in the actual experiments volunteered to get an extra course credit. Participants were presented with the instructions used in the actual experiments, and asked to select the paragraphs they thought were relevant with respect to the instructions. Each participant rated each of the six experimental texts in the version in which the why question was presented at the end of the introductory paragraph. The consistency in rating task relevance of the text paragraphs was very high: 97.8% of the given ratings overlapped with our pre-set definition of relevance. In only 2.2% of the responses the introductory paragraph was rated as the most relevant; it is worth highlighting that none of the responses indicated the irrelevant paragraph as the most relevant of the text.

Procedure

Before the experiment, the eye tracker was calibrated using a 16–point calibration scheme. Calibration was repeated after every two texts. Participants were instructed to read the texts in order to be able to summarize the main contents of the passage, and to answer a question of the text after reading. The instructions were the same for the two groups, except that half of the participants were told that the question will be introduced in the first paragraph of the text (participants from León et al., 2018), whereas the other half were told that the question will be presented after the text (the instructions can be found in the appendix C). Two practice trials preceded the first experimental text to adjust the participants to the eye-tracking equipment. Participants were allowed to read the texts at their own pace. After each text, participants were asked to provide a summary of the text orally, and the responses were recorded. The experimental session took approximately 20 minutes per participant.

The summaries were later scored for the number of words that corresponded with the information presented in the three text paragraphs (introduction, question-relevant, and question-irrelevant). Two independent raters who were blind to the experimental condition scored 30 randomly selected summaries, and as the inter-rater reliability was high (91%, Cohen's Kappa = .81), only one rater scored the rest of the protocols.

Results

Data preparation and statistical analyses

Five paragraph-level eye movement measures were computed from the eye tracking data (see Hyönä, Lorch & Rinck, 2003). The *total fixation time* (measured in seconds) is the summed duration of all fixations landing within the paragraph. The *firstpass reading time* (measured in milliseconds) is the summed duration of fixations done within a paragraph during its first-pass reading. The *look-back duration* (in milliseconds) is the summed duration of fixations that were done on the paragraph after the first-pass reading and that were initially launched to the paragraph from other parts of text. The *number of returns to the introductory paragraph* (frequency), and the *duration of look backs to the introductory paragraph* (measured in milliseconds) reflect how many times readers returned to the introductory paragraph, and for long these visits lasted in total, respectively. The number of fixations included in the total fixation time, firstpass reading time, and look-back duration correlated very highly with the duration measures (r's .98-.99) and thus, they are not reported here for the sake of brevity.

The data were analyzed with linear mixed effects models using the lme4 package (version lme4_1.1-12; Bates, Maechler, Bolker, & Walker, 2015) for R statistical software (version 3.3.2; R Core Team, 2016). Separate models were fitted for each dependent measure: total fixation time, firstpass reading time, look-back duration, number of returns to the introductory paragraph, duration of look backs to the introductory paragraph, and summary task performance (word count). Condition (question in the beginning vs. after the text; manipulated between-subjects independent measure), Relevance (relevant vs. irrelevant; manipulated within-subjects independent measure) and their interaction term were entered as fixed effects to the models. Condition and Relevance were sum coded (-1, 1). Random intercepts for participants and texts were included in the random part of the models [i.e., dependent measure ~ Relevance × Condition + (1|Participant) + (1|Text)]. Interactions were followed by examining simple effects of Relevance at different levels of Condition.

Significant interactions were followed up by computing simple slopes for each condition group. $|T|$-values > 1.96 were considered to indicate a statistically significant effect. The models for each dependent measure are presented in Appendix B.

The descriptive statistics of the eye movement measures as a function of condition and relevance are presented in Table 1.

Table 1. Means and standard deviations for the eye tracking measures as a function of relevance and condition.

		Condition			
		Question in the beginning		Question after text	
Measure	Paragraph	M	SD	M	SD
Total	Relevant	11.21	9.01	8.59	5.10
	Irrelevant	6.14	5.13	8.73	5.50
1st pass	Relevant	6962.57	5224.78	7898.20	5177.94
	Irrelevant	5153.94	4279.09	8186.58	5559.82
Lookbacks	Relevant	4247.37	7307.23	695.70	1738.32
	Irrelevant	983.11	3026.90	541.81	1610.93
Returns	Relevant	1.04	1.31	.28	.52
	Irrelevant	.44	.70	.28	.75
Lookbacks	Relevant	1148.64	2584.04	658.16	2130.63
to intro	Irrelevant	867.78	2957.70	446.81	1369.33

Total = total fixation time (s); 1st pass = firstpass reading time (ms); Lookbacks = look-back duration (ms), Returns = number of returns to the introductory paragraph, Lookbacks to intro = duration of look backs to the introductory paragraph (ms).

Total fixation time

The analysis of the total fixation time showed a main effect of Relevance, b=1.21, 95%CI [.85 – 1.58], *t*=6.50, indicating that total fixation times were overall higher on relevant than irrelevant paragraphs. The effect of condition was not statistically significant, b=.08, 95%CI [-1.12 – 1.27], *t*=.13. However, there was an interaction between Condition and Relevance, b=5.28, 95%CI [3.82 – 6.74], *t*=7.08.

As can be seen in Figure 1, the group that received the question in the beginning of the text showed a sizable relevance effect, which means longer fixation time on relevant than irrelevant paragraphs, b=5.06, 95%CI [4.03 – 6.09], t=9.65. The group that received the question after reading did not show an effect of Relevance, b=-.22, 95%CI [-1.26 – .82], t=-.41.

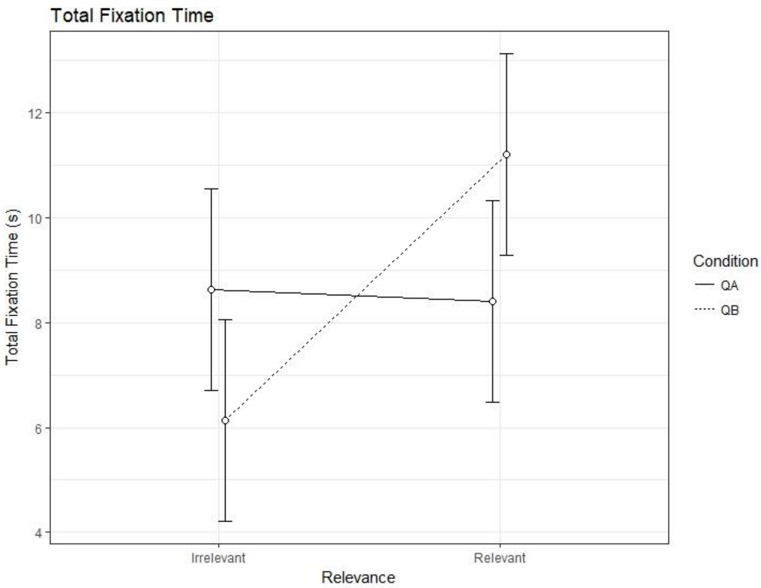

Figure 1. Model estimates for total fixation time on relevant and irrelevant paragraphs as a function of condition. QA= question after the text, QB=question in the beginning of the text. Error bars represent 95% CI's

Firstpass reading time

The analysis of the firstpass reading time revealed a main effect of Relevance, b=360.5, 95%CI [70.50 – 650.46], t=2.44, indicating that first-pass reading times were overall longer on relevant than irrelevant paragraphs. The effect of Condition was not statistically significant, b=-921.0, 95%CI [-1870.26 – 28.35], t=-1.90. However, there was an interaction between Condition and Relevance, b=2182, 95%CI [1022 – 3341.92], t=3.69.

As Figure 2 shows, the group which received the question in the beginning of the text showed longer firstpass reading times on relevant than irrelevant paragraphs, b=1811.9, 95%CI [995.88 – 2628.00], *t*=4.35. On the other hand, the group that received the question after reading did not show an effect of Relevance, b=-370.0, 95%CI [-1194.33 – 454.30], t=-.88. As can be seen in Figure 2, the two groups seem to differ in the time spent on irrelevant paragraphs: readers who were presented with the question in the beginning of the text spend less time on irrelevant paragraphs.

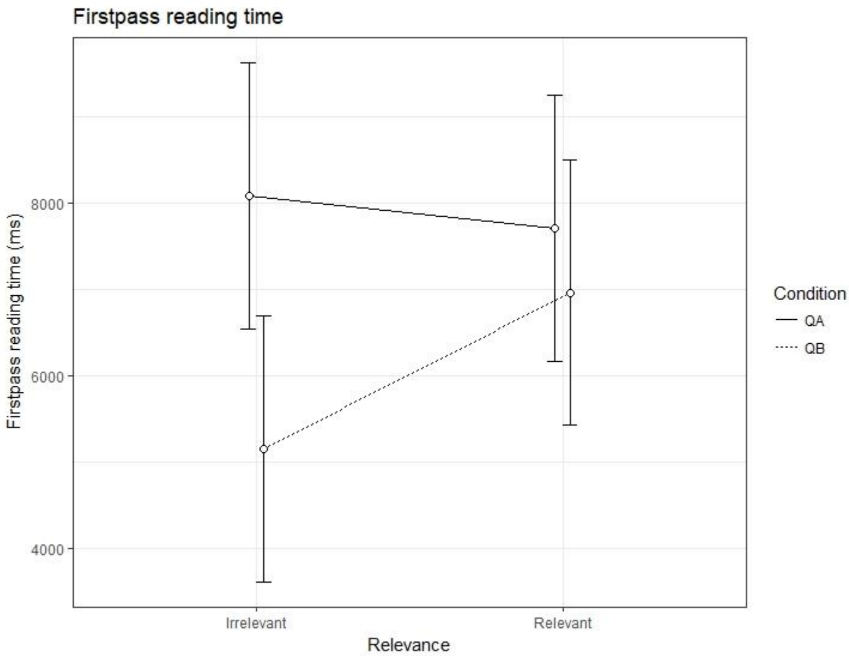

Figure 2. Model estimates for firstpass reading time for relevant and irrelevant paragraphs as a function of condition. QA= question after the text, QB=question in the beginning of the text. Error bars represent 95% CI's

Look-back duration

The results for the look-back duration showed a main effect of Relevance b=850.4, 95%CI [574.08 – 1126.67], *t*=6.03, which is indicating that the overall look-back duration on relevant paragraphs were longer than irrelevant paragraphs. The results showed a main effect of Condition as well, b=996.3, 95%CI [379.25 – 1613.32], t=3.17, showing that the group that received the question in the beginning of the text made longer look-back durations. Moreover, there was an interaction between Condition and Relevance, b=3097.8, 95%CI [1992.64 – 4203.01], t=5.49.

As can be seen in Figure 3, the group that received the question in the beginning of the text showed longer look-back durations on relevant than irrelevant paragraphs b=3249.7, 95%CI [2472.07 – 4027.23], t=8.19. In contrast, the group that received the question after the text did not show an effect of Relevance, b=151.8, 95%CI [-633.53 – 937.19], t=.38. Looking at the Figure 3, it is evident that the groups differ in the time spent looking back to relevant paragraphs: readers who got the question in the beginning of the text made longer lookbacks to relevant text segments.

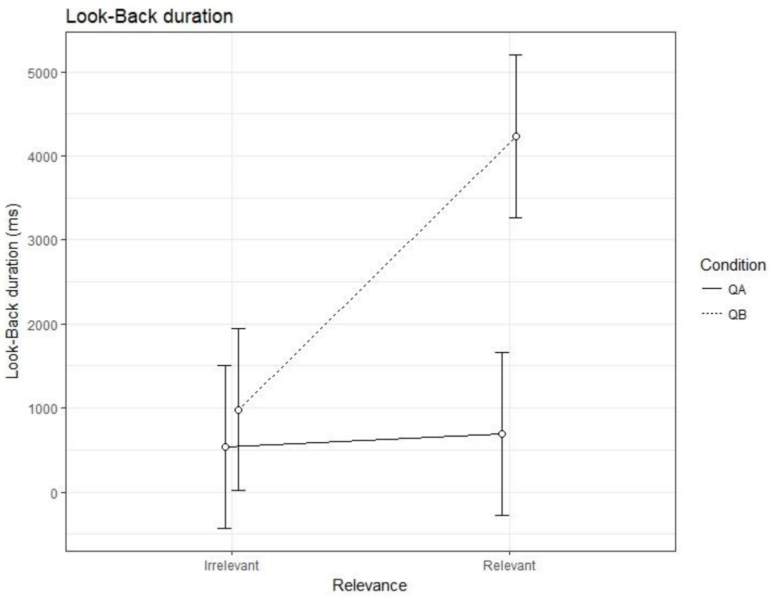

Figure 3. Model estimates for look-back duration for relevant and irrelevant paragraphs as a function of condition. QA= question after the text, QB=question in the beginning of the text. Error bars represent 95% CI's

Number of returns to the introductory paragraph

The results for the number of returns to the introductory paragraph showed a main effect of Relevance, b=.15, 95%CI [.09 – .21], *t*=5.01, which means an overall higher number of returns from relevant than irrelevant paragraphs to the introductory paragraph. There was also a main effect of Condition, b=.22, 95%CI [.10 – .35], *t*=3.51, indicating an overall higher number of returns to the introductory paragraph for participants who received the question in the beginning of the text. The analysis also revealed an interaction between Condition and Relevance, b=.60, 95%CI [.36 – .84], *t*=4.88 (see Figure 4).

Readers who received the question in the beginning of the text made more returns to the introductory paragraph from relevant than irrelevant segments of text, b=.60, 95%CI [.44 – .77], *t*=7.03. The other group did not show such an effect, b=.01, 95%CI [-.16 – .18], *t*=.09. As can be seen in Figure 4, the difference between the conditions (question in the beginning vs. after the text) was in the number of returns from the relevant paragraphs, which was higher in the group that received the question in the beginning of the text.

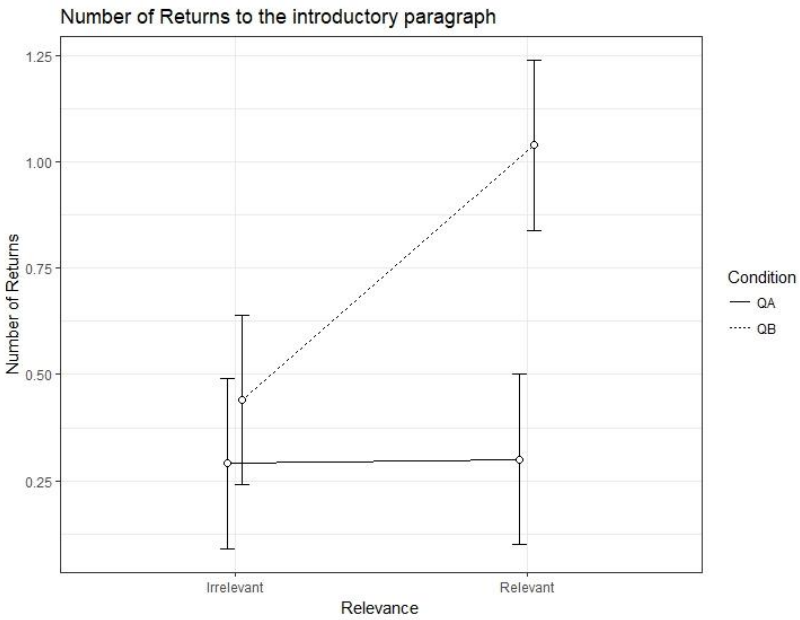

Figure 4. Model estimates for number of returns to the introductory paragraph from relevant and irrelevant paragraphs as a function of condition. QA= question after the text, QB=question in the beginning of the text. Error bars represent 95% CI's

Duration of look backs to the introductory paragraph

There were no effects in the duration of look backs to the introductory paragraph (all t's< 1.96).

Summary task performance (word count)

Finally, we analyzed the number of words retrieved from different parts of the texts (introductory, irrelevant and relevant paragraphs). In the model, paragraph type (introductory, relevant, and irrelevant paragraph) was dummy coded and introductory paragraph served as the baseline. The means and standard deviations for the word count measure as a function of condition and paragraph type are presented in Table 2.

Table 2. Means and standard deviations for the word count as a function of relevance and condition.

	Condition			
	Question in the beginning		Question after the text	
Paragraph	M	SD	M	SD
Introductory	2.04	8.07	2.37	8.23
Irrelevant	1.25	5.31	.28	2.52
Relevant	36.32	20.74	21.57	15.10

The results showed main effect of Relevance, b=9.92, 95%CI [5.76 – 14.09], *t*=4.67, indicating an overall higher recall of words from relevant paragraphs. There was also a main effect of Condition, b=3.55, 95%CI [2.46 – 4.65], *t*=6.35, indicating an overall higher recall for participants who received the question in the beginning of the text. There was also a significant interaction effect between Condition and Relevance (relevant paragraph), b=17.95, 95%CI [13.76 – 22.14], *t*=8.40 (see Figure 5).

Readers who received the question in the beginning of the text showed higher recall of words from relevant than introductory paragraphs, b=35.65, 95%CI [23.20 – 48.10], *t*=5.61. Readers who received the question after the text also showed better recall of words from question-relevant than from introductory paragraphs, but this effect was weaker than in the other group, b=17.70, 95%CI [5.25 – 30.15], *t*=2.79. As can be seen in Figure 5, participants who had the question presented in the beginning of the text produced significantly more words from relevant paragraphs in their summaries than participants in the other group.

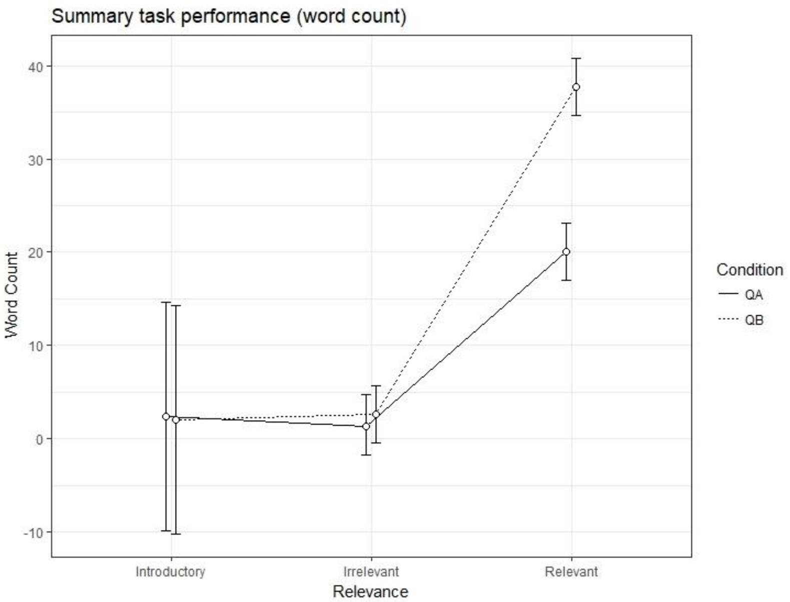

Figure 5. Model estimates for summary task performance (word count) for relevant, irrelevant and introductory paragraphs as a function of condition. QA= question after the text, QB=question in the beginning of the text. Error bars represent 95% CI's

Discussion

In this study, we examined how a why question presented in the beginning of a text influences the processing of and memory for information presented in short expository texts. The results showed that readers who received the question in the beginning of the text, as embedded in the introductory paragraph, showed more selective first-pass reading of the text, as reflected in shorter first-pass reading times of question-irrelevant paragraphs than readers who received the question only after reading. They also did more rereading of the question-relevant text information, as indicated by longer look-back fixation times on question-relevant paragraphs, and returned more often to the introductory paragraph from the question-relevant parts of text than readers who received the question after reading. This selective processing led to better recall of information presented in the question-relevant paragraph.

The results of the present study are in line with the previous research showing that when given a specific question before reading, readers evaluate the importance of text information with respect to the task at hand and invest extra effort into encoding task-relevant information to memory (e.g., Lewis & Mensink, 2012; McCrudden et al., 2010). What the current study clearly demonstrates is that a why-question induces selective processing: readers spend less time on irrelevant information during firstpass reading, in addition to spending more time and effort on relevant text information later. This indicates that readers constantly evaluate the relevance of text information as they read, and if text information is recognized as irrelevant to the task at hand, less effort is invested in its processing. If text information is considered to be relevant for answering the question, extra processing time is invested in it. Moreover, when readers have a specific question in mind, they tend to return from question-relevant parts of text to the segment in which the question was presented, implying that they attempt to build links between the question and the information that is relevant for answering it. This selective processing of text information results in increased recall of question-relevant text information, which replicates findings from previous memory studies (e.g., León & Carretero, 1995; McDaniel & Donnelly, 1996; Ozgungor & Guthrie, 2004; Seifert, 1993; Wood et al., 1990). While it is possible that the recall advantage for relevant information observed in the present study is partly boosted by the question-relevant concepts being activated in the readers' knowledge base, which may facilitate recognizing (ir)relevance of text information and encoding it to memory (Kaakinen & Hyönä, 2007), we claim that the recall advantage reflects selective processing of text information.

Previous eye tracking studies (Kaakinen et al., 2015, Wiley et al., 2010) indicate that rereading and looking back in text is an elementary part of reading for elaborative interrogation. Rereading and looking back in text has been shown to be crucial for comprehension: regressive eye movements and rereading of words within sentences is necessary for sentence comprehension (Schotter, Tran & Rayner, 2014), and looking back to structurally important parts of expository text has been linked with better text comprehension (Hyönä, Lorch, & Kaakinen, 2002). Look-backs are likely to be strategic in nature, meaning that readers know when and where they look back to (Hyönä & Nurminen, 2006). Thus, elaborative interrogation instructions in the form of presenting a why question in the beginning of text seems to induce a specific reading strategy that involves rereading of and looking back to relevant parts of text, as well as looking back from question-relevant text information to the text segment in which the question was presented.

In the present study, participants who received the question in the beginning of text recalled more question-relevant text information than participants who received the question after the text, showing thus a greater relevance effect (i.e. difference between relevant and irrelevant information) in summary performance. Taken together, the present data suggests that the instructions to answer a question presented in the beginning of text prompts students to process question-relevant and task-irrelevant information differently, and that the measures of eye movements and summary task performance are sensitive to these differences.

At this point, it is noteworthy to highlight that there is limited previous research investigating how elaborative interrogation instructions affect the moment-by-moment processing that readers engage in while they are reading a text, and also their performance in a summary task (Kaakinen et al., 2015; Lewis & Mensink, 2012; Wiley et al., 2010). In addition, the most of the research in this field have used sentence-by-sentence reading times as a measure of on-line processes (e.g., Lapan & Reynolds, 1994; McCrudden, 2011; McCrudden et al., 2010; Reynolds et al., 1979). We think that studying readers' eye movement patterns is more informative, since sentence-by sentence reading times do not capture the transitions between different areas of a text as well as eye-movement measures do. Eye movements reveal in more detail how a question that is presented in the beginning of a text can enhance learning from text by revealing how readers inspect and reinspect certain parts of text.

The present results can be explained by the goal-focusing model of relevance proposed by McCrudden and Schraw (2007; McCrudden, 2011). The model was developed to describe how relevance instructions affect reading goals, processing of text information, and learning from expository texts. It identifies two main categories of relevance instructions: *specific relevance instructions*, which prompt readers to focus on precise pieces of information, and *general relevance instructions*, which prompt readers to read for a broader theme or purpose (McCrudden, 2011). The current study compared two types of specific relevance instructions. Why questions presented in the beginning of the text, and why questions presented at the end of the text. According to the model, specific relevance instructions may affect reading goals, processing, and learning at four stages: Relevance cues (stage 1), Goals (stage 2), Resource Allocation (stage 3), and Learning (Stage 4). At the stage 1, specific goal instructions provide explicit cues about what kind of information is relevant to the reading task. Thus, when participants read a why question in the beginning of the text, it provides cues about what kind of information is relevant or irrelevant. When the question is presented only after the text, readers do not have these cues available. The instructions also set the reading goal (stage 2), which is done by using the relevance cues to generate reading goals. A reader instructed to answer a why question presented in the beginning of text, adopts a goal to answer that particular question, whereas a reader who gets the question in the end of the text is likely to adopt a goal of answering any question related to the text at hand. At the stage 3, resource allocation, reading instructions guide readers to allocate attention in ways that help readers identify and process goal-relevant information. Readers in the question in the beginning condition showed greater selectivity in processing as indexed by the eye movement measures, demonstrating longer processing times on relevant than irrelevant text segments in comparison to readers who received the question after reading. Lastly, stage 4 is learning, which refers to the construction of a mental representation of the text. The reading goal formed on the basis of the instructions and the allocation of attention in service of that goal should have an influence on text learning (Magliano, Trabasso & Graesser, 1999). Indeed, in the present study, readers in the question in the beginning condition demonstrated higher learning outcomes – as indexed by the higher number of words recalled – of relevant than irrelevant text information than readers in the question after condition.

It is noteworthy that we managed to observe robust effects of why questions on processing even though the eye tracking methodology utilized in the present study only allowed us to analyze eye movements on a paragraph level, not on the sentence or word levels. A more accurate eye tracking methodology would allow an even more precise analysis of how interrogative elaboration instructions impact the moment-to-moment processes occurring during reading. However, despite describing the reading processes only at the paragraph level, the present results show that the beneficial effect of why questions on comprehension and learning, as demonstrated in previous studies (e.g., Smith et al., 2010), is related to strategic processing of the learning materials.

A recent study (León et al., 2018) found individual differences in the efficiency of making use of elaborative interrogation instructions during the course of reading. This is understandable, as strategic reading requires various cognitive skills and abilities, such as working memory and metacognition. However, the results reported here show that elaborative interrogation induced by specific questions presented in the beginning of text materials seems to facilitate the selection, integration and memory of relevant information within expository texts. Thus, presenting questions either before reading or embedding questions in the beginning of the text (as in the present study) can be recommended as a method to improve learning and memory for question-relevant information. Elaborative interrogation is thus a useful educational tool, as it is likely to increase the understanding and comprehension of expository texts, which often are encountered in educational and learning contexts.

Acknowledgements

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Appendix A

One of the experimental texts (question within the text version):

The Thames

For centuries, London has been exposing the Thames to high levels of contamination. In 1849 it was found that salmon, like the rest of the flora and fauna, had disappeared from the river. The water, though, was still used for human consumption, a fact which led to over 35,000 deaths from diphtheria epidemics between 1831 and 1866. But how did the river become so contaminated?

Because London was a large, heavily populated and industrialized city, the pollution dumped into the river was of a mixed nature. First, the Thames received huge amounts of untreated organic waste from the sewers of London. Second, industries produced chemical waste (such as hydrocarbons, synthetic detergents, phenols, cyanide) that changed the pH of the water. Both types of pollution completely extinguished any form of life in the river.

The contamination led Londoners to avoid the Thames in summer. Every viscous drop of water that passed carried the smell of two centuries of urban pollution. And beneath the surface, the river was dead. In more than 70 kilometers, the water contained almost no oxygen, and fish and other living creatures that inhabited the river had been eliminated long ago. Until the 80´s, the Thames was one of the most polluted rivers in the world.

Appendix B

1. Model for the total fixation time

Random effects			
Group	**Variance**	**SD**	
Participant	18.20	4.27	
Text	.87	.93	
Fixed effects			
	b	**95% CI**	***t***
Intercept	8.62	[6.70 – 10.54]	8.81
Relevance	-.22	[-1.26 – .82]	-.41
Condition	-2.48	[-4.98 – .01]	-1.95
Relevance*Condition	5.28	[3.82 – 6.74]	7.08

2. Model for the firstpass reading time

Random effects			
Group	**Variance**	**SD**	
Participant	11480930	3388.4	
Text	621725	788.5	
Fixed effects			
	b	**95% CI**	***t***
Intercept	8086.8	[6547.45 – 9626.22]	10.30
Relevance	-370.0	[-1194.33 – 454.30]	-.88
Condition	-2932.9	[.4916.79 – -948.99]	-2.90
Relevance*Condition	2182.0	[1022.0 – 3341.92]	3.69

3. Model for the look-back duration

Random effects			
Group	**Variance**	**SD**	
Participant	4275201	2067.7	
Text	25069	158.3	
Fixed effects			
	b	**95% CI**	***t***
Intercept	539.5	[-425.51 – 1504.41]	1.1
Relevance	151.8	[-633.53 – 937.19]	.38
Condition	443.7	[-906.77 – 1794.09]	.64
Relevance*Condition	3097.8	[1992.64 – 4203.01]	5.49

4. Model for the number of returns to the introductory paragraph:

Random effects			
Group	**Variance**	**SD**	
Participant	.17	.41	
Text	.00	.05	
Fixed effects			
	b	**95% CI**	***t***
Intercept	.29	[.09 – .49]	2.89
Relevance	.01	[-.16 – .18]	.09
Condition	.14	[-.13 – .42]	1.03
Relevance*Condition	.60	[.36 – .84]	4.88

5. Model for the duration of look backs to the introductory paragraph:

Random effects			
Group	**Variance**	**SD**	
Participant	489973	700	
Text	85245	292	
Fixed effects			
	b	**95% CI**	***t***
Intercept	453.25	[-39.04 – 945.54]	1.80
Relevance	217.95	[-269.33 – 705.22]	.88
Condition	414.53	[-196.33 – 1025.39]	1.33
Relevance*Condition	57.52	[-628.26 – 743.30]	.16

6. Model for the summary task performance (word count):

Random effects			
Group	**Variance**	**SD**	
Participant	37.78	6.15	
Text	3.10	1.76	
Fixed effects			
	b	**95% CI**	***t***
Intercept	2.35	[-9.89 – 14.59]	.38
Irrelevant	-3.64	[-16.09 – 8.81]	-.53
Relevant	17.70	[5.25 – 8.81]	2.79
Condition	-.28	[-2.58 – 2.03]	-.23
Irrelevant*Condition	4.19	[.01 – 8.36]	1.96
Relevant*Condition	17.95	[13.76 – 22.14]	8.40

Appendix C

Instructions for participants in both conditions.

Condition: Question in the beginning

Participants in the question in the beginning condition were told: “You will read a set of short expository texts. We want you to read the text carefully, focus on the question that appears at the end of the first paragraph, and try to understand as much of the text as possible to answer the question. Later, after reading, you will be asked to give an oral summary about the main ideas of the text including information related to the question to see how well you understood what you have read”.

Condition: Question after the text

Participants in the question after the text condition were told: “You will read a set of short expository texts. We want you to read the text carefully, try to understand as much of the text as possible to answer a question that will appear after you read the text. Later, after reading the question, you will be asked to give an oral summary about the main ideas of the text including information related to the question to see how well you understood what you have read”.

3.4. Relevance instructions combined with elaborative interrogation facilitate strategic reading: Evidence from eye movements

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Abstract

The aim of the present study was to examine effects of relevance instructions and elaborative interrogation on the processing of and memory for expository texts. Eye movements of 105 undergraduate students were tracked while they read expository texts. After reading each text, they produced an oral summary. Participants were divided into three experimental conditions that differed by the presence or absence of the why question and the specific or general relevance instruction they received. Results showed that readers who received the why question embedded in the texts and also received the specific instruction of answering the question demonstrated more strategic reading, as reflected in their first-pass and look-back reading times and also in their better recall of question-relevant information. These results can be readily applied to real-life learning contexts, as they suggest that employing specific relevance instructions in combination with elaborative interrogation may elicit more efficient and strategic reading.

Keywords: eye-tracking, relevance instructions, elaborative interrogation, reading comprehension, strategic processing.

Introduction

Reading can be understood as a goal-directed activity in which the reader has the final purpose of understanding a text (McCrudden & Schraw, 2007). In that sense, the ability of the reader to detect relevant elements is a crucial aspect in order to have a successful comprehension of the text. Thus, relevance instructions can play an important role to facilitate readers to clarify and focus their reading goals, helping them to be more selective in their reading processes, and also to finally have a better understanding of the reading task and the text materials. Based on the comprehensive review of the existing literature on the effects of relevance instructions on reading processes, McCrudden and Schraw (2007; McCrudden, 2011) proposed a model in which they identified two main categories of relevance instructions: specific relevance instructions prompting readers to focus on specific segments of information, and general relevance instructions prompting participants to read for a broader purpose. Their goal-focusing model of relevance establishes four different stages in order to explain how relevance instructions affect reading goal and text processing. In the first stage, the relevance instructions signal what kind of information is relevant in the text. In the second stage, readers generate a reading goal on the basis of the relevance cues. During the third stage readers specifically allocate and direct their attention in order to identify and process the goal-relevant information of the texts. Finally, the fourth stage is related to the construction of the mental representation of the text. In their study, McCrudden, Magliano and Schraw (2010) investigated the mentioned effect of relevance instructions on readers' goals, text processing and memory by giving readers two different relevance instructions related with two specific countries. The results were consistent with previous studies and also with their proposed theoretical framework by showing that readers spent more time reading instruction-relevant than instruction-irrelevant information and also recalled more information about instruction-relevant contents of the text.

In the same way, along the last years it has been showed that having a specific reading perspective in mind when processing an expository text is an efficient way of facilitating selective processing during reading. A considerable amount of research has been devoted to examine possible effects of the adopted reading perspective on reading behavior and on the emerging mental representation of the text. In the seminal study of Anderson and Pichert (1978), the authors did not find consistent effects of the reading perspective on text recall. However, subsequent research succeeded in detecting a perspective effect both on text memory and text processing (Anderson, 1982; Baillet & Keenan, 1986; Goetz, Schallert, Reynolds, & Radin, 1983; Hyönä, Lorch, & Kaakinen, 2002; Kaakinen, Hyönä, & Keenan, 2001, 2002, 2003; Kaakinen & Hyönä, 2005, 2007, 2008, 2011; Kardash, Royer, & Greene, 1988; Lapan & Reynolds, 1994; Lorch, Lorch, & Mogan, 1987; McCrudden, 2011; McCrudden, Magliano & Schraw, 2010; McCrudden & Schraw, 2007, 2009; McCrudden, Schraw, & Kambe, 2005; Rothkopf & Billington, 1979; van den Broek, Lorch, Linderholm, & Gustafson, 2001). In another classic study, Baillet and Keenan (1986) observed a perspective effect when inducing readers to adopt a specific reading perspective of a burglar or an interior designer before reading a story describing three houses. After reading, participants had to recall all the information they could about the story. The results showed that having in mind a specific perspective strongly constrained the recalled information, as readers consistently omitted perspective-irrelevant information in their recalls after reading the text.

In the eye tracking study of Kaakinen, Hyönä and Keenan (2002), participants read an expository text describing four relatively unknown countries. Before reading they were instructed to adopt a specific reading perspective: they were asked to consider the good and bad sides of one of the four countries as a possible new home country. The authors found that the perspective given before reading the text elicited readers to recall more relevant information related to that country than to the other countries. Moreover, the eye movement patterns showed selective processing of the perspective-relevant sections of the text. In another reading study, Kaakinen and Hyönä (2005) analyzed the eye movement patterns and the text recall of participants who read an expository text about several rare illnesses. Participants were given a different and specific perspective related to one of the two possible illnesses before reading the text. Again, the reading perspective generated longer fixation times on perspective-relevant sentences, an effect which emerged already during their initial reading. Also better recall was observed for perspective-relevant than for perspective-irrelevant text information.

Another well-contrasted and efficient method to facilitate learning from an expository text is to instruct readers to seek answers to “why” questions during the course of reading. This method is known as elaborative interrogation and can be understood as a particular type of specific relevance instruction (McCrudden & Schraw, 2007). A considerable amount of research has demonstrated its benefits on the reading processes and also on improving the quality of text memory and comprehension (Callender & McDaniel, 2007; Cerdán, Vidal-Abarca, Martínez, Gilabert, & Gil, 2009; Graesser, 2007; Graesser & Lehman, 2011; Kaakinen, Lehtola & Paattilammi, 2015; Levin, 2008; Lewis & Menskink, 2012; Martin & Pressley, 1991; Smith, Holliday & Austin, 2010; Wiley, Goldman, Graesser, Sanchez, Asch & Hemmerich, 2010; Woloshyn, Pressley, & Schneider, 1992; Wood et al., 1999).

In their eye-tracking study, Lewis and Mensink (2012) showed that participants increased first-pass fixation times and look-back durations for question-relevant sentences in response to questions given prior to reading. Readers also included more information from question-relevant sentences in their subsequent recall protocol. In the study of Smith, Holliday and Austin (2010), students who received why questions while they were reading expository texts obtained better results in a comprehension task than students who only reread the text materials. In the eye-tracking study of Kaakinen, Lehtola and Paattilammi (2015), the authors found that why questions, when presented as titles of a passage, facilitate first-pass reading of the text and also increase integrative processing, as indexed by a higher rate of look-backs within the passage. In a recent eye-tracking study, Moreno, León, Escudero, & Kaakinen (2019) found that readers who received a why question in the beginning of the text showed a selective processing strategy, reflected in longer first-pass fixation times and longer look-back durations on question-relevant than question-irrelevant text segments. These readers also increased the frequency of look-backs from question-relevant paragraphs to the introductory paragraph, which contained the why question. As a result of this selective processing, they had better memory for question-relevant text segments.

Even though previous research suggests that the elaborative interrogation instructions influence both processing of and memory for question-relevant text information, little is known about whether the effects are related to the instructions to answer the questions, or whether the effects are related simply to the presentation of the questions, which may trigger the readers to spontaneously concentrate on question-relevant information. In the present study, we examined how specific instructions to answer a question, and simply presenting a question in the beginning of a text, differ from reading a text without an embedded question. The eye movements of college students were tracked while they read six different expository texts related to general knowledge topics. In addition, they were asked to provide an oral summary about the main contents of each text after reading. Three different instructions were given to the participants prior to reading. One third of them were instructed to read in order to provide an oral summary about the main contents and also to answer a why question that appeared at the end of the first paragraph of each text. Another third of the participants were instructed to read in order to provide an oral summary about the main contents of the text. These participants also received the question inserted at the end of the first paragraph of each text, but they were not specifically instructed to answer it. Finally, the last third of the participants were also instructed to read in order to summarize the main contents of the texts but they did not receive any question inserted at the end of the first paragraph, but instead a neutral sentence replacing it.

We used eye-tracking to study selective processing during text comprehension. It is preferable to sentence reading time measurements, as readers are free to proceed in the text without the need for using a task extraneous to reading (e.g., button pressing). Moreover, it provides a protocol of the reading process as it evolves through time and space. Indeed, eye tracking has proven to be a reliable and informative method to analyze a large variety of processes related to reading (e.g., Hyönä, Lorch, & Rinck, 2003; Rayner, 1998; Rayner & Liversedge, 2011). As reviewed above, it has also been successfully applied to the study of text comprehension. When applied to the present context, it allows us to analyze the time course of selective processing in response to reading instructions, and specifically, to elaborative interrogation.

Based on the goal-focusing model (McCrudden & Schraw, 2007; McCrudden 2011), we expected that presenting a why question toward the beginning of the text and also instructing the readers before reading to specifically pay attention to that question should elicit selective text processing with special attention allocated to the question-relevant contents. In this condition, text is constantly evaluated in the light of the relevance cues, which should manifest as increased first-pass fixation times on question-relevant contents and also as more numerous look-backs both to and from that region. Look-backs to question-relevant contents and to the introduction would reflect rehearsal of that information in memory, possibly in order to integrate the question and question-relevant content with the rest of the text. As a consequence of such selective processing, question-relevant contents should be better represented in oral summaries than question-irrelevant contents. In the condition in which no specific instructions are given but where the question is presented in the beginning of text, there are no specific relevance cues that would help readers to focus on question-relevant information. However, a why-question could function as a weak relevance cue and spontaneously direct readers' attention to question-relevant contents. In this case, the effects may materialize only later, as increased number of look-backs. The resulting oral summary may then include more question-irrelevant information than when readers were given specific instructions to answer the question, as irrelevant information is not initially "filtered". Finally, in the condition in which no question is presented, readers have no relevance cues, and no selectivity in processing or recall is expected.

Method

Participants

One-hundred-and-five psychology students (33 male; age range: 20–23 years) enrolled at a Spanish public university served as the participants. All participants had volunteered to participate in the experiments, and they received course credit as compensation. All participants were native speakers of Spanish (the language used in the materials), and had normal or corrected-to-normal vision.

Apparatus

Eye movements were recorded with an EyeTech™ Digital Systems VT2 infrared eye-tracker. The VT2 has two infrared light sources and an integrated infrared camera. It connects via USB to a Windows computer and captures the eye gaze location (x, y coordinates) at a sampling rate of 80Hz. Registration was binocular, and for cases in which it was not possible, monocular. The camera was fixed under a 15-inch laptop computer on which stimuli were presented to each participant.

Materials

Six expository texts were used as the experimental stimuli with two additional practice texts. Texts were 200-250 words long and they discussed eight different expository topics (the Thames, Mediterranean diet, the suitcase evolution, popcorn history, urban growth, detective novel, insomnia and the greenhouse effect). Each text consisted of three paragraphs, the first of them was always an introduction to the topic (named introductory paragraph), and the other two paragraphs developed the topic of each text (an example of one of the expository texts is presented in Appendix A). There were two different versions of each text: in one version, a why question was inserted at the end of the first paragraph, and in the other version that question was omitted and replaced by a neutral sentence. The topic was developed in the following two paragraphs: one of them included relevant information to answering the question (named relevant paragraph), and the other one contained information that was as such relevant to the topic of the text, but irrelevant for answering the question (named irrelevant paragraph). The order of presentation of the relevant and irrelevant paragraphs was counterbalanced by creating two text versions. Each text was presented on a single page on a computer screen, with a maximum of 20 lines of text per screen.

Eye movement measures

The following paragraph-level eye movement measures were computed from the eye-tracking data (see Hyönä, Lorch & Rinck, 2003). The *total fixation time* (measured in seconds) is the total time spent reading the paragraph. The *first-pass reading time* (measured in milliseconds) is the summed duration of fixations made on the paragraph during the first-pass reading of it before moving to the subsequent paragraph. The *look-back duration* (measured in milliseconds) is the summed duration of fixations returning back to the paragraph after the reader has viewed another paragraph. *The number of returns to the introductory paragraph* refers to the number of times that the reader returned to the introductory paragraph from subsequent parts of the text. The *duration of look backs to the introductory paragraph* (measured in milliseconds) is the summed duration of fixations made during these returns. As the number of fixations and duration measures were very highly correlated, only duration measures will be reported here. Note that the number of returns to the introductory paragraph is not the number of fixations done during look backs; it indicates how many times the reader visited the introductory paragraph after first pass reading.

Procedure

Before the experiment, the eye-tracker was calibrated using a 16–point calibration scheme. Calibration was repeated after every two texts to preserve the accuracy of measurement. Participants were instructed to read the texts in order to be able to summarize the main contents of the passage. Three experimental conditions were tested. In the *question focus* –condition participants were instructed to read the texts in order to be able to summarize the main contents of the passage and to answer a question presented in the first paragraph of the text. In the *question inserted* –condition (n = 32) participants were asked to summarize the main points of each text, but they were not asked to focus specifically on the question presented in the introduction. Finally, in the *summary focus* –condition (n = 33) readers did not receive a question inserted at the end of the first paragraph but were only asked to summarize the main points of each text. The instructions can be found in Appendix B.

Two practice texts preceded the first experimental text to adjust the participants to the eye-tracking equipment. Participants were allowed to read the texts at their own pace. After each text, participants were asked to provide a summary of the text (based on the instructions previously received), and the responses were orally recorded with a voice recorder. The experimental session took approximately 20 minutes per participant.

The summaries were later scored for the total number of words that corresponded with the information presented in the three text paragraphs (introduction, question-relevant, and question-irrelevant). Two independent raters who were blind to the experimental condition scored 30 randomly selected summaries, and as the inter-rater reliability was high (93%; Cohen's Kappa = .82), only one rater scored the rest of the protocols.

Results

Data preparation and statistical analyses

The data were analyzed with linear mixed effects models using the lme4 package (version lme4_1.1-13; Bates, Maechler, Bolker, & Walker, 2015) for R statistical software (version 3.4.3; R Core Team, 2017). Separate models were fitted for each dependent measure: total fixation time, first-pass reading time, look-back duration, number of returns to the introductory paragraph, duration of look-backs to the introductory paragraph, and summary task performance (word count). As the number of fixations and the duration measures were very highly correlated (*r's* .98 - .99), only duration measures are reported here for total reading time, first-pass reading time, and look back time. Note that the number of returns to the introductory paragraph indicates the number of visits to the introductory paragraph after first pass reading — it is thus not a fixation count measure. Condition (Question focus, Question inserted, and Summary focus), Relevance (relevant vs. irrelevant paragraph) and their interaction term were entered as fixed effects to the models of the eye-tracking measures. Condition and Relevance were dummy-coded with the summary focus group and the irrelevant paragraph as the baselines. For the model of the summary task performance (word count), Condition and Paragraph (introductory vs. irrelevant vs. relevant) were entered as dummy-coded fixed effects with the summary focus group and the introductory paragraph as the baselines. To analyze the number of returns to the introductory paragraph, the data were modeled with a generalized linear mixed effects model using Poisson distribution. Random intercepts for participants and texts were included in the random part of the models [i.e., dependent measure ~ Relevance × Condition + (1|Participant) + (1|Text)].

Significant interactions were followed up by computing simple slopes for each summary group. |T|-values > 1.96 were considered to indicate a statistically significant effect. The group differences were examined by interpreting the 95%CI of the estimates that are presented in the figures, which these indicate whether there is a statistically significant difference between the groups (Cumming, 2014; Cumming & Finch, 2005). The models for each dependent measure are presented in Appendix C.

The descriptive statistics of the eye movement measures as a function of relevance and condition are presented in Table 1.

Table 1. Means and standard deviations for the eye tracking measures as a function of relevance and experimental condition.

		Condition					
		Summary focus		Question inserted		Question focus	
Measure	Paragraph	*M*	*SD*	*M*	*SD*	*M*	*SD*
Total	Relevant	8.60	5.50	8.21	5.75	11.77	8.65
	Irrelevant	9.03	5.23	8.85	6.43	6.01	4.46
1st pass	Relevant	7102	4586	6587	4001	7380	5340
	Irrelevant	7218	4497	6652	4373	5247	3810
Look-backs	Relevant	1408	2701	2008	3976	4391	6873
	Irrelevant	1893	3380	1776	4340	761	2569
Returns	Relevant	.44	.73	.54	.89	.93	1.23
	Irrelevant	.45	.69	.63	.81	.39	.65
Look-backs to intro	Relevant	1524	2610	1573	3470	1045	2272
	Irrelevant	1638	2705	1809	3902	863	2683

Total = total fixation time (s); 1st pass = first-pass reading time (ms); Look-backs = look-back duration (ms), Returns = number of returns to the introductory paragraph, Look-backs to intro = duration of look backs to the introductory paragraph (ms).

Total fixation time

The analysis of the total fixation time showed an interaction between Condition (question focus) and Relevance, b=6.21, 95%CI [5.02 – 7.39], t=10.30. Figure 1 shows that the Question focus group (i.e., the group that were prepared to answer the question inserted in the text) had a sizable relevance effect with longer fixation time on relevant than irrelevant paragraphs, b=5.78, 95%CI [4.98 – 6.57], t=14.27. In contrast, neither the Question inserted group, b=-.57, 95%CI [-1.46 – .32], t=-1.26, nor the Summary focus group, b=-.43, 95%CI [-1.31 – .44], t=-.96, showed an effect of relevance. As is evident from Figure 1, the Question focus group spent less time on irrelevant and more time on relevant paragraphs than the two other groups.

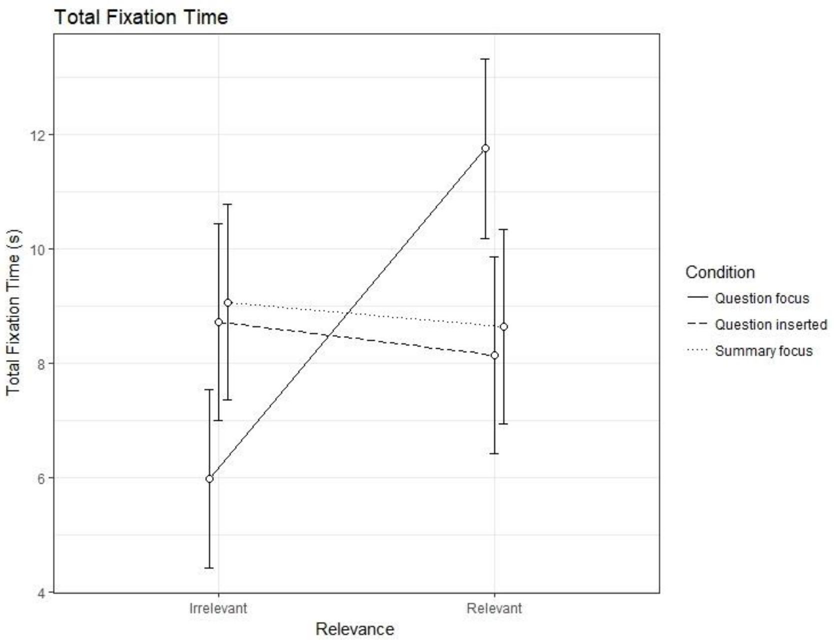

Figure 1. Model estimates for total fixation time on relevant and irrelevant paragraphs as a function of condition. Error bars represent 95% CI's.

First-pass reading time

The analysis of the first-pass reading time yielded an interaction between Condition (question focus) and Relevance, b=2260.59, 95%CI [1328.59 – 3192.59], *t*=4.75. As can be seen in Figure 2, the Question focus group showed longer first-pass reading times on relevant than irrelevant paragraphs, b=2144.9, 95%CI [1518.81 – 2770.92], *t*=6.72. On the other hand, neither the Question inserted group, b=-125.65, 95%CI [-826.57 – 575.28], *t*=-.35, nor the Summary focus group, b=-115.72, 95%CI [-806.14 – 574.70], *t*=-.33, showed a significant relevance effect. As can be seen in Figure 2, the group difference emerged in the time spent on irrelevant paragraphs: the readers of the Question focus group spent less time on irrelevant paragraphs than the readers of the other two groups.

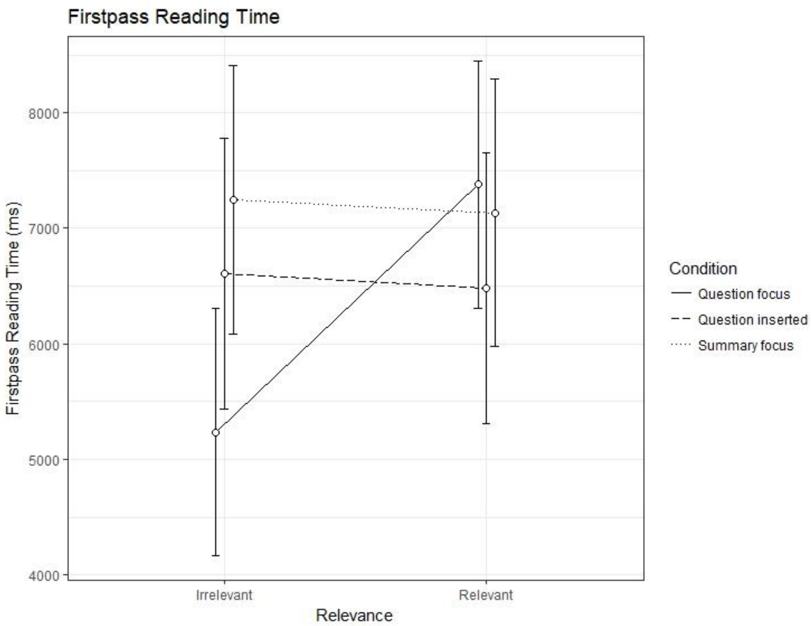

Figure 2. Model estimates for first-pass reading time for relevant and irrelevant paragraphs as a function of condition. Error bars represent 95% CI's.

Look-back duration

The results for the look-back duration demonstrated an interaction between Condition (question focus) and Relevance, b=4114.5, 95%CI [3224.70 – 5004.38], *t*=9.06. Figure 3 shows that the readers in the Question focus group produced a clear relevance effect, b=3629.2, 95%CI [3031.47 – 4226.94], *t*=11.90, indicating longer look-back durations on relevant than irrelevant paragraphs. In contrast, the Question inserted group did not show an effect of relevance, b=203.0, 95%CI [-466.22 – 872.22], *t*=.60, neither did the Summary focus group, b=-485.3, 95%CI [-1144.53 – 173.85], *t*=-1.44. As it appears from Figure 3, the groups mainly differed in the time spent looking back to relevant paragraphs: the participants of the Question focus group made longer lookbacks to relevant paragraphs than the participants of the other two groups.

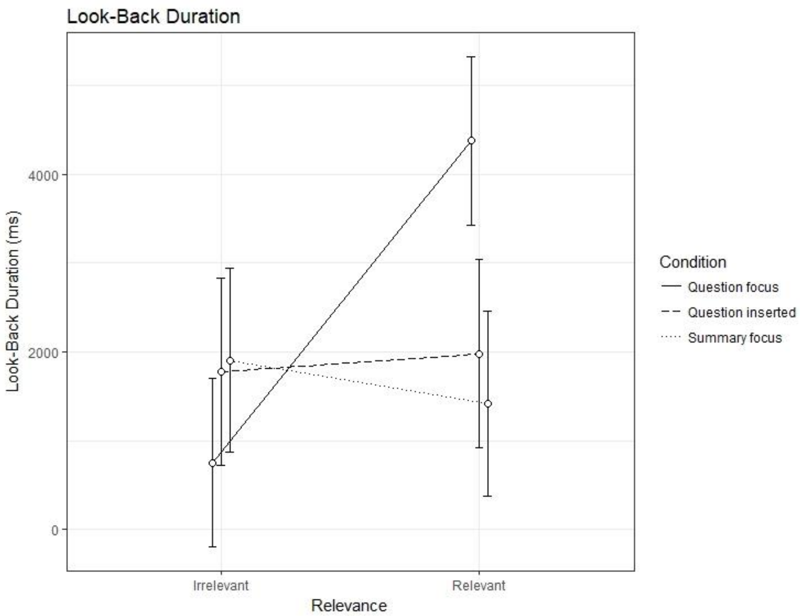

Figure 3. Model estimates for look-back duration for relevant and irrelevant paragraphs as a function of condition. Error bars represent 95% CI's.

Number of returns to the introductory paragraph

The analysis of the number of returns to the introductory paragraph revealed an interaction between Condition (question focus) and Relevance, b=.89, 95%CI [.52 – 1.27], z=4.68. As can be seen in Figure 4, the Question focus group demonstrated a clear relevance effect, b=.86, 95%CI [.62 – 1.10], z=7.10; the readers in this group made a significantly greater number of returns to the introductory paragraph from the relevant than irrelevant paragraphs. Neither the Question inserted group, b=-.17, 95%CI [-.43 – .09], z=-1.27, nor the Summary focus group, b=-.03, 95%CI [-.32 – .26], z=-.23, showed an effect of relevance. Figure 4 shows that the main difference between the three experimental groups was in the number of returns made from the relevant paragraphs, being higher for the Question focus group.

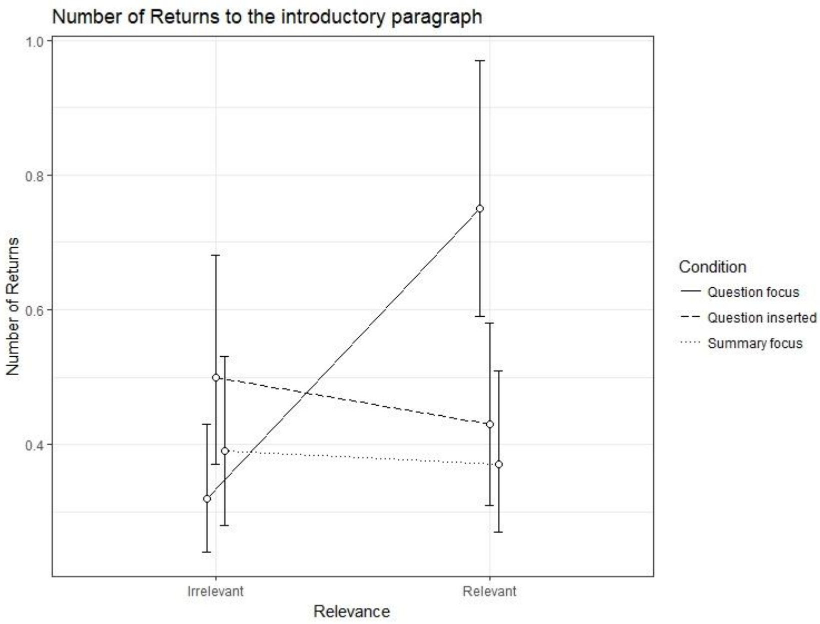

Figure 4. Model estimates for number of returns to the introductory paragraph from relevant and irrelevant paragraphs as a function of condition. Error bars represent 95% CI's.

Duration of look backs to the introductory paragraph

There were no effects in the duration of look-backs to the introductory paragraph (all t's< 1.96).

Summary task performance

Finally, we analyzed the number of words retrieved from the three paragraphs (introductory, relevant, and irrelevant paragraphs) of each text. In order to fit the model, paragraph type (introductory, relevant, and irrelevant paragraph) was dummy coded with the introductory paragraph serving as the baseline. The means and standard deviations for the word count measure as a function of condition and paragraph type are presented in Table 2.

Table 2. Means and standard deviations for the summary task performance (word count) measure as a function of relevance and condition.

	Condition					
Paragraph	Summary focus		Question inserted		Question focus	
	M	*SD*	*M*	*SD*	*M*	*SD*
Introductory	34.56	15.84	31.13	20.17	2.16	8.52
Irrelevant	25.64	19.29	24.83	21.10	2.34	8.05
Relevant	37.18	19.50	47.08	26.09	37.40	22.10

The analysis of the summary task performance revealed a significant interaction between Condition (question focus) and Relevance (relevant paragraph), b=32.65, 95%CI [28.63 – 36.67], *t*=15.91. There was a clear effect of relevance (relevant paragraph) in the Question focus group, b=35.24, 95%CI [32.53 – 37.96], *t*=25.47, and also in the Question inserted group, b=15.95, 95%CI [12.90 – 19.01], *t*=10.24, but this effect was not statistically significant for the Summary focus group, b=2.60, 95%CI [-.37 – 5.57], *t*=1.72. The relevance effect was greater for the Question focus group than for the Question inserted group. In addition, as can be seen in Figure 5, the three groups mainly differed in the number of words they produced in their summaries concerning the information of the irrelevant paragraphs: the readers of the Question focus group produced significantly less words contained in the introductory and irrelevant paragraphs than the readers of the other two groups.

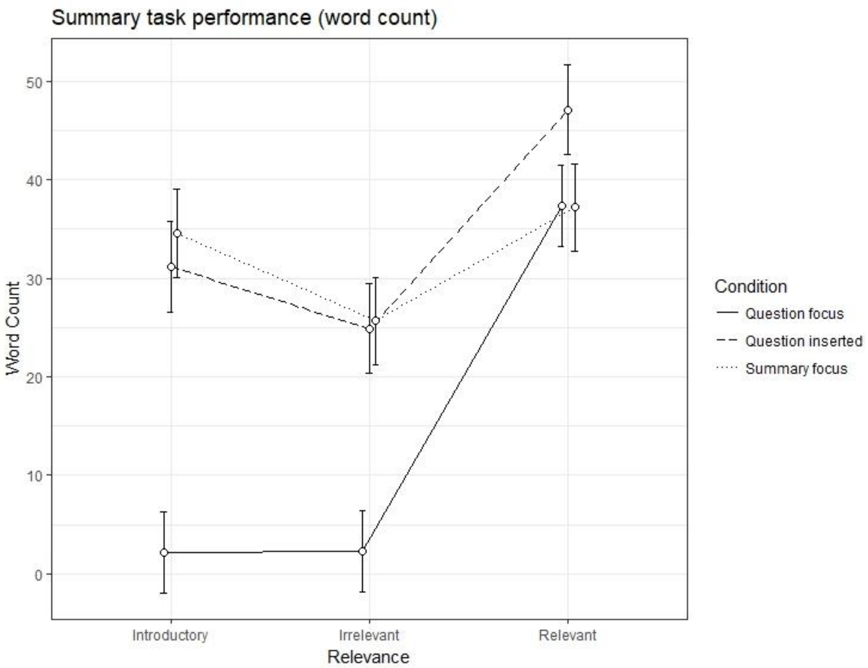

Figure 5. Model estimates for summary task performance (word count) for relevant, irrelevant and introductory paragraphs as a function of condition. Error bars represent 95% CI's

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Discussion

In the present study, we examined the effects of relevance instructions and elaborative interrogation on the processing of and memory for question-relevant and question-irrelevant information of expository texts. The results showed that readers who received the why question located in the first paragraph of the texts and also received the specific instruction of answering the question demonstrated more strategic reading (Hyönä et al., 2002) than readers who received other instructions before facing the texts. Readers assigned to this experimental condition demonstrated selective reading behavior both in first-pass and look-back measures. Participants of the Question focus condition were the only group of the three that showed a relevance effect. During the first-pass reading this effect emerged as less time devoted to the question-irrelevant paragraph, and during the second-pass reading the effect emerged as additional time dedicated to the question-relevant paragraph and also as increased returns to the introductory paragraph. These readers were also selective in what information was encoded to memory, as reflected in less information recalled from the introductory and the question-irrelevant paragraphs. The recall data show that having in mind a specific instruction to focus on answering the why question inserted in the text has clear consequences for how introductory and question-irrelevant information is included in the summaries.

The results reported in this work are congruent with previous research on reading instructions and elaborative interrogation (e.g., Graesser & Lehman, 2011; Kaakinen et al., 2002, 2003; Kaakinen & Hyönä, 2008, Lewis & Menskink, 2012; McCrudden et al., 2010; McCrudden & Schraw, 2007). In the present study, the why question seemed to guide the readers to process more deeply information relevant for answering that question, and at the same time to process less central information more superficially.

Similarly, Kaakinen et al. (2003) found that perspective-relevant information was devoted more time than perspective-irrelevant information, which also resulted in better memory for relevant than irrelevant information. The pattern of results obtained in the present study is also in line with the results Kaakinen and Hyönä (2008) observed for reading narrative texts and with the framework of perspective-driven text comprehension put forth by the authors. According to the framework, a specific reading perspective activates concepts in the reader's knowledge base relevant to the reading perspective, and directs attention to perspective-relevant text information, which results in improved memory for perspective-relevant information.

The present results are also congruent with the goal focusing model proposed by McCrudden and Schraw (2007; McCrudden, 2011). Stage 1 of the model is related to the relevance instructions given to the readers. In the present study, instructing a group of participants before reading to pay special attention to the question presented at the end of the first paragraph gave them specific cues about what information is relevant and irrelevant in the text, as opposed to giving the readers general relevance instructions of summarizing the main contents of the text, which did not activate specific cues about the relevant information. Stage 2 is referred to as goal formation; readers generate reading goals based on the relevance cues activated by the instructions. In this study, readers who had in mind a specific instruction about focusing on the why question adopted a goal to specifically answer that question, whereas readers who received general relevance instructions about summarizing the main contents of the text adopted a wider goal for processing the text. In Stage 3, readers allocate their attention in order to detect goal-relevant information. In the present study, readers who received the specific relevance instruction about answering the question explicitly directed their attention to the question-relevant information and away from question-irrelevant information, while readers who received general relevance instructions (i.e., the question-inserted and the summary-focus condition readers) did not show selective processing during reading. Finally, Stage 4 is related to the construction of a memory representation of the information read. As applied to the present study, Stage 4 materialized for readers who received the specific instruction about focusing on the question as better recall of question-relevant information than question-irrelevant information, which was clearly underrepresented in their memory. The two other groups, on the other hand, showed relatively good recall of information presented in the introductory and question-irrelevant paragraphs, indicating that they constructed a more representative memory of the text. Thus, it seems that the selectivity during processing, induced by instructions to focus on answering the question, comes at the cost of not gaining memory for task-irrelevant information.

As noted above, readers in the question inserted group also showed better recall of question-relevant than question-irrelevant information. However, they were not as selective in their recall as readers in the question focus group, as they showed overall better recall of information presented in the introductory and the question-irrelevant paragraphs than the question focus group. The performance of the question inserted group suggests that question-relevant information can be encoded to memory without paying increased attention to it. One possible explanation for this pattern of results is that a question inserted in the text activates question-related knowledge in the reader's knowledge base, which facilitates encoding of text information to memory (see also Kaakinen et al., 2015). Even though the combination of more general instructions to read in order to summarize the text contents and an inserted question seems to be the winning condition with respect to memory performance, we would like to note that this result was unexpected. Unfortunately we cannot exclude the possibility that readers in this group simply had superior text comprehension skills, which may also explain the differences in the memory performance.

On a more general level, the findings of the present research can be also understood on the basis of the RESOLV framework proposed by Britt, Rouet and Durik (2017). According to this framework, intentional reading constitutes a problem-solving situation, which can be understood as a goal-directed activity that is embedded in a situational context. The authors propose that purposeful reading is always based on the mental representation readers make about the task and the context, and consequently that these internal representations lead to specific reading decisions and processes. In this framework, once the reading context has been interpreted by the reader, this context and also the specific motivation of the reader determine the reading goal, and subsequently what kind of information the reader will extract from the text. By applying the RESOLV framework to the present study, our main results may be interpreted to indicate that the reading goal activated by the different relevance instructions given to the readers clearly conditioned the reading strategies they employed, the way they processed the texts, and also the final product of their memory representation.

Regarding the limitations of the present study, the eye-tracking technology employed for this research allowed us to analyze eye movement patterns on a paragraph level, not on the sentence or word level. Despite this limitation, we managed to detect robust effects of the reading instructions and elaborative interrogation on the reading behavior. Employing a more accurate eye-tracking apparatus would allow a finer level of analysis in order to inspect the moment-to-moment processes taking place during the course of reading. Nonetheless, analyzing the eye movement patterns on the paragraph level showed in a consistent way the benefits of employing specific relevance instructions in encouraging strategic and selective reading behavior and facilitating the learning and comprehension processes (see also e.g., Kaakinen et al., 2003).

Another obvious limitation of the present study is that the reading instructions were manipulated between participants. Even though the statistical analysis applied in the present study takes into account the random variance between participants, we cannot exclude the possibility that the groups differed in, e.g., text comprehension skills, which could explain the observed pattern of results. However, participants were sampled from the same population of university students and randomly assigned to the different reading instruction groups. Moreover, manipulating the reading instruction within participants is not feasible, as the experimental session would become significantly longer, which may induce carry-over effects from previous conditions as well as changes in reading patterns caused by fatigue. Thus, we considered the between-participants design preferable to the within-participants design.

To conclude, the present results show that employing specific relevance instructions in combination with elaborative interrogation elicit more efficient and strategic reading processes and, consequently, may result in improved comprehension of task-relevant text materials. In other words, providing cues that help readers to form clear goal structures and to engage in goal-focused processing of text information seems to be helpful (see also Britt et al., 2017). Thus, training students to form clear reading goals and employ different processing strategies to fulfill those goals is a potentially fruitful instructional method to improve reading efficiency and learning from text.

Appendix A

One of the experimental texts (why-question inserted in the text) translated from Spanish to English

The Thames

For centuries, London has been exposing the Thames to high levels of contamination. In 1849 it was found that salmon, like the rest of the flora and fauna, had disappeared from the river. The water, though, was still used for human consumption, a fact which led to over 35,000 deaths from diphtheria epidemics between 1831 and 1866. But how did the river become so contaminated?

Because London was a large, heavily populated and industrialized city, the pollution dumped into the river was of a mixed nature. First, the Thames received huge amounts of untreated organic waste from the sewers of London. Second, industries produced chemical waste (such as hydrocarbons, synthetic detergents, phenols, cyanide) that changed the pH of the water. Both types of pollution completely extinguished any form of life in the river.

The contamination led Londoners to avoid the Thames in summer. Every viscous drop of water that passed carried the smell of two centuries of urban pollution. And beneath the surface, the river was dead. In more than 70 kilometers, the water contained almost no oxygen, and fish and other living creatures that inhabited the river had been eliminated long ago. Until the 80´s, the Thames was one of the most polluted rivers in the world.

One of the experimental texts (why-question replaced by a neutral sentence) translated from Spanish to English

The Thames

For centuries, London has been exposing the Thames to high levels of contamination. In 1849 it was found that salmon, like the rest of the flora and fauna, had disappeared from the river. The water, though, was still used for human consumption, a fact which led to over 35,000 deaths from diphtheria epidemics between 1831 and 1866. Thus it continued for a long time.

Because London was a large, heavily populated and industrialized city, the pollution dumped into the river was of a mixed nature. First, the Thames received huge amounts of untreated organic waste from the sewers of London. Second, industries produced chemical waste (such as hydrocarbons, synthetic detergents, phenols, cyanide) that changed the pH of the water. Both types of pollution completely extinguished any form of life in the river.

The contamination led Londoners to avoid the Thames in summer. Every viscous drop of water that passed carried the smell of two centuries of urban pollution. And beneath the surface, the river was dead. In more than 70 kilometers, the water contained almost no oxygen, and fish and other living creatures that inhabited the river had been eliminated long ago. Until the 80´s, the Thames was one of the most polluted rivers in the world.

Appendix B

Instructions for participants in all conditions.

Question focus condition

Participants in the question focus condition were told: "You will read a set of short expository texts. We want you to read the text carefully, focus on the question that appears at the end of the first paragraph, and try to understand as much of the text as possible to answer the question. Later, after reading, you will be asked to give an oral summary about the main ideas of the text including information related to the question to see how well you understood what you have read".

Question inserted and summary focus conditions

Participants in the question inserted and summary focus conditions were told: "You will read a set of short expository texts. We want you to read the text carefully, understanding as much of the text as possible. Later, after reading, you will be asked to give an oral summary about the main ideas of the text to see how well you understood what you have read."

Appendix C

1. Model for the total fixation time

Random effects			
Group	**Variance**	***SD***	
Participant	18.33	4.28	
Text	.59	.77	
Fixed effects			
	b	**95% CI**	***t***
Intercept	9.07	[7.37 – 10.77]	10.45
Relevance	-.43	[-1.31 – .44]	-.96
Question inserted	-.35	[-2.61 – 1.91]	-.30
Question focus	-3.09	[-5.29 – -.94]	-2.82
Relevance*Question inserted	-.14	[-1.39 – 1.11]	-.22
Relevance*Question focus	6.21	[5.02 – 7.39]	10.30

2. Model for the firstpass reading time

Random effects			
Group	**Variance**	***SD***	
Participant	7538737	2746	
Text	350425	592	
Fixed effects			
	b	**95% CI**	***t***
Intercept	7247.36	[6089.45 – 8405.27]	12.27
Relevance	-115.72	[-806.14 – 574.70]	-.33
Question inserted	-638.44	[-2143.06 – 866.19]	-.83
Question focus	-2011.94	[-3438.80 – -585.08]	-2.76
Relevance*Question inserted	-9.93	[-993.78 – 973.93]	-.02
Relevance*Question focus	2260.59	[1328.59 – 3192.59]	4.75

3. Model for the look-back duration

Random effects			
Group	**Variance**	***SD***	
Participant	7252277	2693	
Text	36904	192.1	
Fixed effects			
	b	**95% CI**	***t***
Intercept	1907.3	[865.37 – 2949.19]	3.59
Relevance	-485.3	[-1144.53 – 173.85]	-1.44
Question inserted	-130.8	[-1598.30 – 1336.73]	-.18
Question focus	-1156	[-2547.65 – 235.63]	-1.63
Relevance*Question inserted	688.3	[-251.02 – 1627.69]	1.44
Relevance*Question focus	4114.5	[3224.70 – 5004.38]	9.06

4. Model for the number of returns to the introductory paragraph

Random effects			
Group	**Variance**	***SD***	
Participant	.42	.65	
Text	.00	.03	

Fixed effects			
	b	**95% CI**	***z***
Intercept	-.95	[-1.26 – -.64]	-6.02
Relevance	-.03	[-.32 – .26]	-.23
Question inserted	.26	[-.16 – .69]	1.22
Question focus	-.19	[-.61 – .23]	-.90
Relevance*Question inserted	-.13	[-.52 – .26]	-.67
Relevance*Question focus	.89	[.52 – 1.27]	4.68

5. Model for the duration of look backs to the introductory paragraph

Random effects			
Group	**Variance**	***SD***	
Participant	1983094	1408.2	
Text	27481	165.8	

Fixed effects			
	b	**95% CI**	***t***
Intercept	1630	[1013.79 – 2246.15]	5.19
Relevance	-113.8	[-625.68 – 398.05]	-.44
Question inserted	181.5	[-674.88 – 1037.90]	.42
Question focus	-770.2	[-1582.59 – 42.21]	-1.86
Relevance*Question inserted	-136.1	[-865.49 – 593.26]	-.37
Relevance*Question focus	295.8	[-395.15 – 986.77]	.84

6. Model for the summary task performance (word count)

Random effects			
Group	**Variance**	***SD***	
Participant	107.33	10.36	
Text	4.79	2.19	

Fixed effects			
	b	**95% CI**	***t***
Intercept	34.58	[30.11 – 39.05]	15.16
Irrelevant	-8.95	[-11.91 – -5.98]	-5.91
Relevant	2.60	[-.37 – 5.57]	1.72
Question inserted	-3.41	[-9.32 – 2.49]	-1.13
Question focus	-32.46	[-38.02 – -26.90]	-11.45
Irrelevant*Question inserted	2.67	[-1.59 – 6.93]	1.23
Irrelevant*Question focus	9.13	[5.11 – 13.14]	4.45
Relevant*Question inserted	13.35	[9.09 – 17.61]	6.15
Relevant*Question focus	32.65	[28.63 – 36.67]	15.91

4. CONCLUSIONES

4.1. General conclusions

As it has been introduced in previous sections, the main objective of this doctoral dissertation has been to apply the methodology of analysis of the eye movement patterns to study the effect of relevance instructions and inserted "why" questions on the processing strategies and reading comprehension of expository texts.

It should be noted that the main results observed from the empirical studies of this dissertation indicate that providing specific relevance instructions, as well as inserted "why" questions, or the combination of both, elicit readers to use a strategic and selective processing during the reading tasks. This selective processing is reflected in the online eye movement measures, showing higher firstpass and rereading times for question-relevant information compared to irrelevant, and also in the offline measures of the quality of the recall from the oral summaries produced after reading, showing higher recall rates for question-relevant information compared to irrelevant. In addition, we would like to emphasize that the results found are consistent for each of the six expository texts that have been expressly generated for the studies of this dissertation.

Before synthesizing some of the main conclusions that can be drawn from each of the studies, it is worth highlighting some of the main general contributions that can be extracted from all of them. In the studies developed within the framework of this dissertation, the advantages of the use of the eye tracking methodology have been put in value, compared to other methodologies such as measuring reaction times, demonstrating that reading processes and their evolution in space and time can be studied more accurately, as well as the possibility of differentiating between the study of the firstpass reading and the rereadings. In addition, we would like to emphasize again the advantages of combining this type of online methodology with offline measures about the quality of the recall, such as the oral summaries produced by the participants. The combination of both kind of measures has showed to be very informative, since it has allowed us to triangulate with greater precision the reading behavior in each moment of the task, from the beginning, going through each of the processing phases, until reaching the final product, which is the summary itself. In this way, we have been able to verify that there is a close relationship between the reading patterns, reflected in the eye movement measures, and the information included in the summaries of the texts made by the readers. Finally, it is also important to point out that, taking into account the results found in these studies, potential educational implications are inferred, that may be relevant for learning environments. As it has been shown, the implementation and application of specific relevance instructions and inserted "why" questions, can offer consistent benefits to learning and understanding when facing students to reading tasks related to expository texts, promoting and facilitating more efficient, strategic and selective reading processing, which can finally lead to an improved understanding and learning from texts.

4.1. Conclusiones generales

Tal y como se introducía en apartados anteriores, a nivel general, el objetivo principal de la presente tesis doctoral ha sido analizar el efecto de las instrucciones de relevancia y de preguntas adjuntas sobre las estrategias de procesamiento y la comprensión lectora de textos expositivos mediante la metodología de análisis de los patrones de movimientos oculares.

Cabe destacar que los principales resultados que se desprenden de los tres estudios empíricos indican que proporcionar instrucciones específicas de relevancia, así como preguntas adjuntas de tipo "por qué", o la combinación de ambas, induce en los lectores un procesamiento estratégico y selectivo en las tareas de lectura que llevan a cabo. Este procesamiento selectivo se refleja tanto en las medidas online de movimientos oculares, mostrando tiempos de lectura y relectura superiores para la información relevante frente a la irrelevante, como en las medidas offline de calidad del recuerdo y de los resúmenes orales producidos después de leer, en las que se muestran tasas de recuerdo superiores para la información relevante frente a la irrelevante. Adicionalmente, queremos destacar también que los resultados encontrados son consistentes en cada uno de los seis textos expositivos que han sido expresamente generados para los estudios de esta tesis.

Antes de pasar a sintetizar algunas de las principales conclusiones que pueden extraerse de cada uno de los estudios, cabe resaltar algunos de los principales aportes que pueden deducirse de todos ellos. En los estudios desarrollados en el marco de esta tesis se han puesto en valor las ventajas de la utilización de la metodología de análisis de los patrones de movimientos oculares frente a otras metodologías como la medición de los tiempos de reacción, demostrando que se pueden estudiar con mayor precisión los procesos de lectura y su evolución en el espacio y en el tiempo, así como la posibilidad de diferenciar entre el estudio de la primera lectura y de las relecturas. Adicionalmente, nos gustaría destacar nuevamente las ventajas de combinar este tipo de metodología online con medidas offline sobre la calidad del recuerdo, como son los resúmenes orales producidos por los participantes. La combinación de ambos tipos de medidas ha resultado ser muy informativa, puesto que nos ha permitido triangular con mayor precisión cómo es la conducta lectora en cada uno de los momentos de la tarea, desde el inicio, pasando por cada una de las fases de procesamiento, hasta llegar al producto final, que es el propio resumen. De este modo, hemos podido comprobar que existe una relación estrecha entre los patrones de lectura, reflejados en las citadas medidas de movimientos oculares, y la información incluida en los resúmenes de los textos realizados por los lectores. Finalmente, también creemos relevante destacar que, de los resultados encontrados en estos estudios, se desprenden potenciales implicaciones educativas que pueden ser relevantes en entornos de aprendizaje. Tal y como se ha demostrado, la implementación y aplicación de instrucciones específicas de relevancia y de preguntas adjuntas de tipo "por qué", puede ofrecer beneficios consistentes en el aprendizaje y la comprensión a la hora de enfrentar a los estudiantes a tareas de lectura y de análisis de textos expositivos, promoviendo y facilitando estilos de procesamiento lector más eficientes, estratégicos y selectivos, que desemboquen al mismo tiempo en una comprensión y un aprendizaje mejorados de los textos.

4.2. Conclusiones específicas de cada estudio

4.2.1. Conclusiones del estudio 1: Age differences in eye movements during reading. Degenerative problems or compensatory strategy? A meta-analysis

En este primer estudio y, sobre la base de los resultados sintetizados y analizados de los 22 experimentos incluidos en el meta-análisis, se ofrecen las estimaciones combinadas de los tamaños del efecto que encontramos al comparar las diferencias de edad encontradas en las principales medidas de movimientos oculares empleadas para analizar procesos de lectura. Este meta-análisis ofrece información sustantiva respecto a lo que hasta el momento podía encontrarse en la literatura previa, en forma de revisiones cualitativas. Se aprecia una variación sustancial en los tamaños del efecto a lo largo de los 22 experimentos analizados, y adicionalmente se encuentran algunas variables que moderan los efectos observados. Los resultados obtenidos en este meta-análisis son consistentes con los hallazgos de la gran mayoría de los estudios previos en el campo, en los que se compara el rendimiento en tareas de lectura entre adultos jóvenes y adultos mayores. En general, en la mayoría de los estudios que han comparado lectores jóvenes con lectores mayores se llega a la conclusión de que los adultos mayores tienden a leer más despacio, a hacer fijaciones más largas, movimientos sacádicos más amplios, un mayor número de regresiones, y a saltar palabras con mayor frecuencia (e.g., Kemper et al., 2004; Kliegl et al., 2004; McGowan, White, Jordan, & Paterson, 2013; Rayner et al., 2011). Las conclusiones a las que se llega en este meta-análisis son válidas para todas las medidas de movimientos oculares analizadas, excepto la medida “*mean number of fixations*”, cuya estimación combinada del tamaño del efecto no alcanzó un valor significativo. Consideramos estas estimaciones informativas en la medida en que confirman estadísticamente los patrones más comunes que se pueden observar en la literatura, ofreciendo al mismo tiempo una visión integrada sobre el estado de la cuestión en este campo. Adicionalmente, los datos del meta-análisis no permiten descartar ninguna de las dos hipótesis generales que aparecen de forma recurrente en la literatura, que son las relativas a los problemas neurológicos degenerativos asociados con el envejecimiento, y el desarrollo de potenciales estrategias compensatorias de lectura. De este modo, una de las principales conclusiones de este estudio es que lo más razonable por el momento es mantener la idea de que ambas hipótesis tienen respaldo a la luz de los datos, y que además son compatibles y complementarias entre sí, ya que ambas en conjunción pueden explicar los cambios que se observan en la conducta lectora a consecuencia del proceso de envejecimiento.

Adicionalmente, cabe destacar que este meta-análisis ha resultado también de gran utilidad a la hora de alcanzar los dos objetivos de investigación relacionados con la estructura de la presente tesis doctoral, que fueron previamente planteados en capítulos anteriores. Por una parte, nos ha permitido identificar y sintetizar algunas de las principales medidas de movimientos oculares empleadas para analizar el procesamiento lector, lo cual ha resultado de gran ayuda a la hora de plantear los estudios empíricos de esta tesis. Por otra parte, también nos ha permitido determinar que el grupo de edad de adultos jóvenes es el más competente en tareas de lectura, lo que también ha resultado de utilidad a la hora de plantear los objetivos y la recogida de datos para los estudios empíricos.

4.2.2. Conclusiones del estudio 2: Specific relevance instructions promote selective reading strategies: Evidences from eye tracking and oral summaries

En el presente estudio se analiza cómo el tipo de instrucción de relevancia afecta a la forma en la que los lectores procesan los textos, teniendo en cuenta sus patrones de movimientos oculares, así como la calidad del recuerdo en una posterior tarea de lectura. Los principales resultados muestran que las instrucciones generales y específicas de relevancia tienen una influencia fuerte en las estrategias de codificación y procesamiento que los lectores expertos emplean durante la lectura, promoviendo dos tipos distintos de procesos de lectura, como son las estrategias de lectura selectivas y no selectivas. De este modo, los participantes de la condición con instrucción específica de relevancia activaron una estrategia selectiva de procesamiento que les llevó a reconocer los segmentos relevantes del texto con mayor eficiencia, lo cual puede apreciarse en sus patrones de movimientos oculares, ya que estos lectores realizaron fijaciones más duraderas y con mayor frecuencia, así como un mayor número de regresiones, sobre los segmentos relevantes del texto frente a los irrelevantes. Adicionalmente, estos participantes recordaron proporcionalmente también una mayor cantidad de contenido de los párrafos relevantes de los textos en sus resúmenes orales. Por contra, los participantes que recibieron la instrucción general de relevancia llevaron a cabo una estrategia de procesamiento no selectiva, caracterizada por no dedicar tiempo adicional ni un mayor número de fijaciones y regresiones a procesar los fragmentos relevantes de los textos frente a los irrelevantes. Al resumir, estos participantes recordaron indistintamente contenidos de todos los párrafos de los textos, sin hacer mayor hincapié en la información de los párrafos relevantes.

Este estudio añade varios puntos de interés frente a lo realizado hasta el momento en la literatura previa, ya que muestra el valor de combinar medidas online, como es el registro de medidas de movimientos oculares durante la lectura, y offline, como la generación de un resumen oral sobre los contenidos del texto después de leerlo, a la hora de examinar la influencia de las instrucciones de relevancia sobre el procesamiento y la comprensión de textos en la misma investigación. Combinar ambos tipos de datos nos permite explicar por qué algunos lectores dedican más o menos tiempo a leer información irrelevante en los textos y por qué producen resúmenes tan dispares sobre los mismos. Empleando al mismo tiempo medidas online y offline, hemos sido capaces de identificar diferencias importantes en los objetivos y en las estrategias de lectura de los lectores que, de otro modo, hubieran permanecido ocultas, así como en los resultados relativos a la calidad de su recuerdo. Los resultados del presente estudio sugieren que el tipo de instrucción de relevancia influye en cómo los lectores desarrollan estrategias para alcanzar sus objetivos de lectura, y cómo estas estrategias influyen en la memoria. Combinando toda esta información, estos datos muestran de forma empírica que las instrucciones de relevancia afectan a las intenciones y a los objetivos de lectura, lo cual afecta a su vez al procesamiento de la información relevante e irrelevante para alcanzar esa meta de lectura que, finalmente, afecta también al producto final que es la representación de esa información en la memoria de los lectores.

4.2.3. Conclusiones del estudio 3: Impact of elaborative interrogation instructions on the processing of expository texts: An eye movement study

En el presente estudio, se examina cómo una pregunta adjunta de tipo "por qué" (*"why" question*), presentada al inicio de un texto influye en el procesamiento y en la memoria de la información de varios textos expositivos. Los principales resultados de este estudio muestran que los lectores que recibieron la pregunta al inicio del texto mostraron un procesamiento más selectivo durante la primera lectura del mismo (*first-pass reading*), reflejado en tiempos de lectura más cortos para los párrafos irrelevantes para la pregunta, que los lectores que recibieron la pregunta únicamente después de leer cada texto. De igual modo, estos participantes también realizaron más relecturas (*second-pass reading*) de los párrafos que contenían información relevante para la pregunta, lo cual se reflejó en tiempos de refijación más duraderos en los párrafos relevantes para la pregunta, y un mayor número de regresiones al párrafo introductorio, que contenía la pregunta, desde los párrafos relevantes para la misma, que aquellos lectores que recibieron la pregunta después de leer los textos. Adicionalmente, este procesamiento selectivo condujo a su vez a estos participantes a un mejor recuerdo de la información presentada en los párrafos relevantes para la pregunta, lo cual quedó reflejado en sus resúmenes orales.

Los resultados de este estudio muestran con claridad que una pregunta adjunta de tipo "por qué" induce a un procesamiento selectivo de los textos, ya que lleva a los lectores a dedicar menos tiempo a la información irrelevante durante la primera lectura, y haciendo además que dediquen más tiempo y esfuerzo a esa información relevante en las posteriores relecturas. Esto indica que los lectores están constantemente evaluando la relevancia de la información del texto mientras leen y que, si parte de esta información se reconoce como irrelevante para la tarea de lectura que estén llevando a cabo, le dedicarán menos esfuerzo a su procesamiento. Adicionalmente, cuando los lectores tienen una pregunta específica en mente, tienden a volver desde las partes del texto que son relevantes para esa pregunta al segmento del texto en el que la pregunta fue presentada, como un claro intento de construir enlaces entre la pregunta y la información que es relevante para contestarla. Finalmente, tal y como muestran los resultados del presente estudio, este procesamiento selectivo del texto termina desembocando también en un mayor recuerdo de la información relevante.

4.2.4. Conclusiones del estudio 4: Relevance instructions combined with elaborative interrogation facilitate strategic reading: Evidence from eye movements

En el presente estudio, se examinaron los efectos tanto de instrucciones de relevancia generales y específicas como de preguntas adjuntas de tipo "por qué" en el procesamiento y la memoria de información relevante e irrelevante para esas preguntas, en un conjunto de textos expositivos. Los resultados de este estudio muestran que los lectores que recibieron las preguntas al inicio de cada texto, en el primer párrafo de los mismos, y que adicionalmente recibieron la instrucción específica de responder a esa pregunta, demostraron unos patrones de lectura más estratégicos en sus movimientos oculares que aquellos lectores que recibieron otras instrucciones antes de leer los textos. Los lectores asignados a esta condición experimental demostraron un comportamiento lector selectivo tanto en la primera lectura (*first-pass reading*) como en las relecturas (*second-pass reading*), dedicando menos tiempo de fijaciones durante la primera lectura al párrafo irrelevante para la pregunta, y dedicando a su vez tiempo adicional al párrafo relevante para la pregunta e incrementando las refijaciones al párrafo introductorio, que contenía la pregunta, durante las relecturas. Adicionalmente, los lectores de esta condición fueron también selectivos en lo que respecta a la información que codificaron en la memoria, ya que dedicaron menos información en sus resúmenes orales a los contenidos de los párrafos introductorios y de los irrelevantes para la pregunta. Por tanto, los datos sobre la calidad del recuerdo muestran que tener en mente una instrucción específica que focalice la atención en una pregunta adjunta en el texto tiene consecuencias claras en la forma en la que la información de los textos se incluye y se estructura en los resúmenes.

Los resultados de este estudio muestran que emplear instrucciones específicas de relevancia en combinación con preguntas adjuntas de tipo "por qué" promueve procesos de lectura más eficientes y estratégicos y, por consiguiente, puede desembocar también en una comprensión mejorada de los materiales de los textos relevantes para la tarea. De este modo, proporcionar pistas a los lectores que les ayuden a generar objetivos claros y estructurados y que les facilite a su vez el procesamiento dirigido por esos objetivos de la información del texto, se perfila como un método potencialmente útil en contextos instruccionales y de aprendizaje (e.g., Britt et al., 2017).

4.3. Limitaciones y otras líneas de estudio

Como ya se ha resaltado previamente en algunos de los estudios que han sido descritos en líneas anteriores, una de las principales limitaciones con la que hemos trabajado durante el desarrollo de los experimentos de la presente tesis doctoral ha sido el aparato de medición de los movimientos oculares empleado durante los registros, que contaba con una tasa de refresco de 80Hz. Las características de este aparato únicamente nos han permitido registrar medidas online de movimientos oculares a nivel de párrafo. A pesar de ello, a lo largo de los estudios previamente descritos, hemos sido capaces de detectar de forma eficiente efectos robustos de las instrucciones de lectura y de las preguntas adjuntas en el comportamiento lector. Emplear un aparato de registro de los movimientos oculares más preciso nos permitiría conseguir un nivel más fino de análisis a la hora de inspeccionar lo que sucede en los procesos online que tienen lugar durante el curso de la lectura. A pesar de ello, creemos que, en función de los objetivos planteados para los estudios de esta tesis, el párrafo es la unidad de análisis natural, así como una de las más informativas. De este modo, analizando los movimientos oculares a nivel de párrafo hemos mostrado de forma consistente los beneficios de emplear instrucciones específicas de relevancia y preguntas adjuntas para potenciar el comportamiento lector estratégico y selectivo, facilitando a su vez los procesos de aprendizaje y comprensión de textos (ver también e.g., Kaakinen et al., 2003; McCrudden & Schraw, 2007; McCrudden et al., 2010), lo cual, pensamos, es uno de los principales valores añadidos de los estudios de la presente tesis.

Otra limitación común a los estudios experimentales aquí planteados es que las instrucciones de lectura siempre se manipularon de forma inter sujeto. A pesar de que el tipo de análisis estadístico aplicado en los presentes estudios tiene en cuenta la varianza aleatoria inter sujeto, no podemos excluir la posibilidad de que los grupos de participantes difirieran entre sí en cuestiones como, por ejemplo, las habilidades de comprensión de textos. Sin embargo, las muestras de participantes de todos los estudios fueron siempre recogidas de la misma población de estudiantes universitarios y asignados de forma aleatoria a los distintos grupos en función de sus instrucciones de lectura. Adicionalmente, cabe resaltar que manipular las instrucciones de lectura de forma intra sujeto no es factible, ya que la sesión experimental se haría mucho más larga, lo cual terminaría introduciendo de forma irremediable efectos de arrastre de las anteriores condiciones, así como cambios en los patrones de lectura a causa de la fatiga. Por todo ello, creemos que el diseño inter sujeto empleado en los experimentos previamente expuestos es preferible a un diseño intra sujeto.

Adicionalmente, cabe resaltar que una de las líneas de trabajo que se derivan directamente de la presente tesis doctoral es la del estudio de las diferencias individuales de los sujetos en las distintas tareas de lectura. En este punto, nos gustaría introducir brevemente otro experimento que hemos llevado a cabo a raíz de este planteamiento, en el que empleamos la metodología de movimientos oculares para examinar las diferencias individuales de los lectores al enfrentarse a las peticiones de una tarea de lectura específica. En las siguientes líneas trataremos de sintetizar las principales claves y resultados que se desprenden del citado estudio que, actualmente, está siendo revisado para su publicación en una revista internacional de impacto (Léon, Moreno, Escudero, & Kaakinen, 2019).

Partiendo de la premisa de que la comprensión lectora y la habilidad para resumir están estrechamente relacionadas, cabe esperar que el procesamiento estratégico y selectivo durante la lectura se refleje de igual modo en resúmenes de alta calidad. Tal y como se mencionaba en líneas anteriores, el objetivo de este estudio fue el de aplicar la metodología de movimientos oculares para analizar cómo procesan los textos aquellos lectores que producen resúmenes de alta calidad. Para tal fin, 40 estudiantes universitarios fueron instruidos para leer una serie de textos expositivos presentando especial atención a una pregunta adjunta introducida siempre al inicio de cada texto (instrucción específica de relevancia). Después de leer, los participantes debían producir un resumen oral sobre el texto. La calidad de los resúmenes de los participantes fue evaluada y puntuada en función de criterios de contenido y coherencia. Posteriormente, los participantes fueron divididos en tres grupos distintos en función de la calidad de sus resúmenes, alta, media y baja calidad. Algunos de los principales resultados del estudio muestran que los lectores que producen resúmenes de alta calidad realizan, de manera significativa, fijaciones más duraderas y más numerosas, así como un mayor número de regresiones a las partes del texto relevantes para la pregunta, en comparación con los participantes pertenecientes a los otros dos grupos de resumen. Estos resultados parecen indicar que el desempeño en una tarea de resumen puede ser un buen predictor de las estrategias de procesamiento empleadas durante la lectura.

Del mismo modo, estos resultados muestran que, pese a partir de las mismas condiciones, no todos los lectores son capaces de emplear una estrategia de atención selectiva de la manera más eficiente. Estas diferencias individuales pueden estar relacionadas con ciertas limitaciones cognitivas, tales como la capacidad de memoria de trabajo (e.g., Kaakinen et al., 2001; 2003), o conocimientos sobre estrategias eficientes de procesamiento lector (e.g., Hyönä et al., 2002). Por ello, pensamos que estudios futuros deberían examinar con mayor detalle las claves y las bases de estas diferencias individuales.

Finalmente, nos gustaría terminar resaltando también que posibles líneas futuras de investigación deberían considerar la aplicación de instrucciones de relevancia y de preguntas adjuntas a entornos de aprendizaje, con el fin de optimizar la comprensión de los lectores y, al mismo tiempo, de alinear sus objetivos de lectura y las claves de relevancia con los planes instruccionales de los docentes. Tal y como destacan McCrudden et al. (2010), es importante alinear los objetivos de aprendizaje, con las propias tareas de aprendizaje y la posterior evaluación de lo aprendido. No cabe duda de que la habilidad para distinguir entre contenido relevante e irrelevante en respuesta a instrucciones específicas de la tarea de lectura es una competencia clave que los lectores deben desarrollar para llegar a ser más efectivos como lectores y aprendices.

A modo de corolario, quisiéramos destacar que entrenar a los estudiantes a formar objetivos claros de lectura y a emplear distintas estrategias de procesamiento para cumplir con estos objetivos se presenta como un método potencialmente fructífero en contextos instruccionales para mejorar la eficiencia lectora y el aprendizaje de los textos.

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Note: References marked by a * are those that were included in the meta-analysis reported here.

6. ANEXOS

6.1. Textos en español

El Támesis

Durante siglos, Londres ha estado sometiendo al Támesis a una contaminación de gran calibre. Fue en 1849 cuando se detectó que habían desaparecido de las aguas del río el salmón al igual que el resto de fauna y la flora. Las aguas del río aún se utilizaban para el consumo humano, lo que dio lugar a epidemias de difteria con más de 35.000 muertos entre 1831 y 1866. Pero, ¿cómo se contaminó el río?

Por sus características de gran ciudad muy poblada e industrializada, la contaminación vertida sobre el río era de carácter mixto. Por una parte, el Támesis era el lugar donde iban a parar una ingente cantidad de residuos orgánicos proveniente de los desagües de Londres y donde no se contaba con tratamientos de depuración eficiente. Por otra, las industrias producían residuos químicos (hidrocarburos, detergentes sintéticos, fenoles, cianuros…) que cambiaban el pH de las aguas. Ambos tipos de contaminación extinguieron por completo la vida en el río.

La contaminación llevó a que los londinenses evitaran las orillas del Támesis en verano. Cada gota de agua pegajosa que pasaba llevaba el olor de dos siglos de contaminación urbana. Y, bajo la superficie, el río estaba muerto. En más de 70 kilómetros de recorrido, las aguas no contenían prácticamente nada de oxígeno, y los peces y otros seres vivos que las poblaban habían sido eliminados hacía tiempo. El Támesis fue hasta la década de los 80 uno de los ríos más contaminados del mundo.

Palomitas de maíz

Cuando los españoles llegaron a las tierras americanas fueron recibidos por indios americanos que les ofrecían, en muestra de bienvenida, collares hechos con palomitas de maíz. No debe sorprendernos que el maíz fuese una gramínea oriunda de aquellas tierras y que los amerindios la llevasen consumiendo desde hace más de seis mil años. Pero, ¿qué es lo que hace que un grano de maíz se transforme en una palomita de maíz?

Los amerindios ya conocían la diferencia entre maíz dulce, que debía consumirse enseguida, y maíz duro, destinado a la molienda. Sin embargo, no todos los tipos de maíz son válidos para hacer palomitas. Sólo un tercer tipo de maíz indio, una mezcla de ambos, servía para ello. El maíz ha de tener un 14% de agua para que, bajo los efectos del calor, ésta se expanda y se evapore, provocando el estallido, convirtiéndose en esa masa esponjosa que son las flores de maíz, o palomitas.

Con la aparición en 1907 de la primera máquina eléctrica de hacer palomitas en EE.UU. se extendió su consumo. A su popularidad también contribuyó un hecho ajeno al maíz mismo: la costumbre de entretener la tensión que el cine provocaba ingiriendo los espectadores grandes cantidades de palomitas de maíz. No había cine americano que no tuviese en su antesala a un vendedor de este popular alimento. Fue en el cine donde las palomitas de maíz alcanzaron sus niveles de consumo más altos, y su consagración.

La maleta

Desde hace mucho tiempo el hombre ha viajado por diferentes motivos, utilizando para sus desplazamientos y según la época, muchos y variados tipos de equipaje. Cofres, baúles o arcones fueron de los más utilizados, pero éstos resultaban muy voluminosos y pesados. Otros fueron las zamarras o alforjas, pero éstas resultaban muy frágiles y de escasa capacidad. Pronto se vio la necesidad de cambiar este tipo de equipaje por otro más ligero y práctico como es la maleta. Pero ¿qué razones propiciaron este cambio?

Tras la Segunda Guerra Mundial, el turismo floreció. Con el creciente uso de aviones, aumentaron las limitaciones del volumen y peso del equipaje, lo que hizo necesario que las maletas se hicieran cada vez más reducidas y ligeras. Además, con la llegada de nuevos inventos como la cremallera, el nylon y otras fibras artificiales, fueron rápidamente introducidos por los fabricantes de maletas generando modelos más útiles, reducidos y ligeros.

Tras la llegada de sucesivos hallazgos se desarrollaron modelos más prácticos, reducidos y ligeros, tanto que llamaron la atención del famoso escritor irlandés y premio Nobel de Literatura, Bernard Shaw, quién señaló "No acabo de entender por qué la mujer necesita cada vez maletas más grandes, siendo así que cada vez su ropa necesita menos tela", haciendo alusión a su carácter satírico y burlón, presente en todas sus obras.

La dieta mediterránea

Transmitida de generación en generación, la dieta mediterránea está íntimamente vinculada al estilo de vida de los pueblos mediterráneos a lo largo de su historia. Se caracteriza por la abundancia de alimentos vegetales, como pan, pasta, arroz, verduras, hortalizas, legumbres, frutas y frutos secos; el empleo de aceite de oliva como fuente principal de grasa; consumo moderado de pescado, marisco, aves de corral, productos lácteos (yogur, quesos) y huevos; el consumo reducido de carnes rojas y aportes diarios de vino consumido generalmente durante las comidas. Pero, ¿por qué es saludable?

Su importancia en la salud del individuo no se limita al hecho de que sea solo una dieta equilibrada y variada. Posee beneficios por su bajo contenido en ácidos grasos saturados, por su riqueza en sustancias antioxidantes, en carbohidratos complejos y en fibra. Sus efectos positivos son tan evidentes que los científicos han relacionado esta dieta con una menor incidencia de enfermedades como el cáncer o las enfermedades cardiovasculares, lo que se traduce en una mayor esperanza de vida.

La dieta mediterránea abraza a todos los pueblos de la cuenca mediterránea, constituidos de paisajes, cultivos y técnicas de cultivo, de mercados, de espacios y gestos culinarios, de sabores y perfumes, de tertulias y celebraciones, de leyendas, de innovación y tradición. Ha ido evolucionando, incorporando sabiamente nuevos alimentos, fruto de la posición geográfica estratégica y también de la capacidad de mestizaje e intercambio de los pueblos mediterráneos. La dieta mediterránea continúa siendo un patrimonio cultural evolutivo, dinámico y vital.

El crecimiento urbano

En el mundo de hoy, las ciudades crecen sin cesar y el proceso de urbanización se acelera progresivamente en todo el planeta. En la actualidad hay más población urbana que rural y todo hace prever que en 2050 más del 70% de la población mundial vivirá en las ciudades. Pero ¿qué es lo que mueve a las personas a emigrar a las grandes ciudades?

El crecimiento urbano proviene, en su mayor parte, del éxodo de la población rural. La progresiva degradación de las condiciones de vida en el mundo rural contrasta con la fuerte atracción de las ciudades, que suelen ofrecer mayores oportunidades de puestos de trabajo, una gran concentración de inversión económica, una elevada cantidad y variedad de servicios y numerosos centros de intercambio cultural y tecnológico.

El crecimiento de la ciudad ha generado las denominadas aglomeraciones urbanas, que comprenden áreas circundantes en torno a una gran ciudad. Estas aglomeraciones urbanas pueden tener diferentes extensiones que van desde un área metropolitana que agrupa una ciudad y la zona urbana que la rodea hasta una megalópolis, cuya zona urbana alcanza cientos de kilómetros de extensión como ocurre en Nueva York o Tokio.

La novela policíaca

La novela policíaca es un tipo de relato donde se narra la historia de un crimen. El esquema básico de este tipo de narraciones es que una vez que sucede un crimen misterioso e inexplicable, un sagaz detective investiga el caso analizando minuciosamente los hechos y sus circunstancias, encontrando finalmente la solución. La novela policíaca goza de una enorme popularidad, especialmente entre lectores jóvenes y urbanos. Pero ¿por qué interesa más a lectores jóvenes y urbanos?

El interés de la novela policíaca para este segmento de población reside en que mantiene la tensión e intriga a lo largo de todo el texto, con un desenlace sorprendente e inesperado. Además, el relato policial es netamente urbano y, además, el protagonista suele ser una persona joven, intrépida y dinámica, y con un fuerte atractivo sexual. El lector joven suele identificarse con el investigador y vive en primera persona las pesquisas que reconstruyen el crimen hasta dar con el asesino.

El relato policial es netamente urbano y nació a la vez que los cuerpos de seguridad en las ciudades europeas y norteamericanas a comienzos del siglo XIX. En la novela policíaca, los principales personajes, el detective, el asesino o el delator, suelen ser estáticos, no sufren evolución alguna a lo largo del relato. A Edgar Allan Poe se le considera el padre de la novela policiaca, creador del primer detective literario, Auguste Dupin, que sirvió de inspiración al celebérrimo Sherlock Holmes.

Texto de prueba: El insomnio

El insomnio es un trastorno común del sueño. Uno de cada tres adultos suele sufrir algún problema para dormir. Las personas que sufren de insomnio tienen dificultades para quedarse dormidas, para continuar durmiendo o para hacer ambas cosas. A consecuencia de esto, duermen muy poco, muy mal o de manera discontinua. Por ello es probable que, al despertar, se sientan cansadas. Pero, ¿cuáles son las causas del insomnio?

Existen varios tipos de factores responsables. Hay factores ambientales como el ruido, cambios de luz y temperatura. También influyen los hábitos poco saludables, como el consumo de tabaco, alcohol o bebidas excitantes. Hay, además, algunos factores fisiológicos, como problemas respiratorios, dolores crónicos o la reacción a ciertos fármacos. Y, por último, están los factores psicológicos, originados por la preocupación ante problemas laborales, familiares o personales, los exámenes o problemas de salud.

La falta de sueño puede interferir en la habilidad para trabajar, en la rapidez de reflejos (por ejemplo, al conducir), en las capacidades intelectuales y de concentración y en la sensación de bienestar general. Cuando el insomnio es persistente, es conveniente consultar a un médico, ya que la falta de sueño puede llevar al abuso o uso inadecuado de medicinas e incluso del alcohol, que pueden aumentar y prolongar el problema.

Texto de prueba: El efecto invernadero

El efecto invernadero es un fenómeno por el cual los gases que se encuentran en la atmósfera retienen el calor emitido por la Tierra. Este calor proviene de la natural radiación solar, pero cuando rebota sobre la superficie terrestre queda atrapado por la barrera de gases. Al quedarse estos gases entre suelo y atmósfera, el efecto producido a escala planetaria es muy similar al de un invernadero. El efecto invernadero es la principal causa del calentamiento global. Pero, ¿por qué no se escapa el calor de la atmósfera?

Los gases que retienen el calor son principalmente el dióxido de carbono y el metano. Estos gases han existido desde los orígenes de la Tierra. Pero su presencia en la atmósfera empezó a multiplicarse durante la Revolución Industrial, momento en el que los avances tecnológicos obligaron al uso de combustibles fósiles. A partir de entonces, esta dinámica no ha hecho más que incrementarse, alcanzando un 35% más de dióxido de carbono que en los niveles pre-industriales.

Algunas de las lúgubres predicciones sobre el futuro de la civilización en la Tierra realizadas por los climatólogos son, por ejemplo, el deshielo de los casquetes polares, subida del nivel del mar, deforestación, desertización, huracanes y tifones, sequía, lo que llevará a la escasez de alimentos y guerras por la tierra, por el agua potable y por los recursos naturales. Debemos revisar nuestro modelo energético, apostar por las energías renovables y gestionar mejor nuestros recursos energéticos.

6.2. Textos en inglés

The Thames

For centuries, London has been exposing the Thames to high levels of contamination. In 1849 it was found that salmon, like the rest of the flora and fauna, had disappeared from the river. The water, though, was still used for human consumption, a fact which led to over 35,000 deaths from diphtheria epidemics between 1831 and 1866. But how did the river become so contaminated?

Because London was a large, heavily populated and industrialized city, the pollution dumped into the river was of a mixed nature. First, the Thames received huge amounts of untreated organic waste from the sewers of London. Second, industries produced chemical waste (such as hydrocarbons, synthetic detergents, phenols, cyanide) that changed the pH of the water. Both types of pollution completely extinguished any form of life in the river.

The contamination led Londoners to avoid the Thames in summer. Every viscous drop of water that passed carried the smell of two centuries of urban pollution. And beneath the surface, the river was dead. In more than 70 kilometers, the water contained almost no oxygen, and fish and other living creatures that inhabited the river had been eliminated long ago. Until the 80´s, the Thames was one of the most polluted rivers in the world.

Popcorn

When the Spanish arrived in America they were welcomed by American Indians who offered them necklaces made of popcorn. It shouldn’t surprise us, because corn was a native grain of those lands and the Amerindians had been consuming it for more than six thousand years. But, how does a grain of corn turn into popcorn?

Amerindians already knew the difference between sweet corn, which should be consumed immediately, and hard corn, which could be ground. However, not all types of corn are suitable for making popcorn. Only a third type of Indian corn, a mixture of the two, was used for this. Corn has to contain 14% water so that under the effects of heat it expands and evaporates, causing it to explode and become a spongy mass of flowers of corn, or popcorn.

With the appearance in 1907 of the first electric popcorn machine in the US, consumption spread. Its popularity was also contributed to by a practice which had nothing to do with corn itself: the spectators’ habit of relieving the tension caused by the movie by eating large amounts of popcorn. There wasn’t an American cinema that did not have a vendor of this popular food in its vestibule. It was at the movies where the consumption of popcorn reached its highest levels, and where it was consecrated.

The Suitcase

For years people have been travelling for different reasons and using, depending on the distance and the period, many different types of luggage. Chests, trunks and wooden cases were the most common, but they were very bulky and heavy. Others were saddlebags or sacks made from animal skin, but these were frail and couldn't carry much. Soon it became necessary to change this type of baggage to one that was more lightweight and practical, such as the suitcase. But, what were the reasons that led to changes in suitcases?

After the Second World War, tourism began to flourish. With the increasing use of aircraft, it became necessary to introduce limits on the size and weight of baggage, causing suitcases to become smaller and lighter. Moreover, new inventions such as the zipper, nylon, and other synthetic fibers, were quickly incorporated by manufacturers of suitcases to produce even smaller, lightweight and more useful models.

Successive advances led to the development of more practical, smaller and lighter models, which prompted the famous Irish writer and Nobel laureate, George Bernard Shaw, to comment in his typical satirical and mocking way; "I do not quite understand why women need ever larger suitcases when their clothes are made with less and less fabric."

The Mediterranean Diet

Passed down from generation to generation, the Mediterranean diet is closely linked to the lifestyle of Mediterranean people throughout history. It is characterized by an abundance of plant foods such as bread, pasta, rice, vegetables, legumes, fruits and nuts; the use of olive oil as the principal source of fat; Moderate consumption of fish, seafood, poultry, dairy products (yogurt, cheese) and eggs; reduced consumption of red meat and daily intake of wine generally consumed at meals. But, why is the Mediterranean diet healthy?

Its importance to a person's health is not only due to the fact that it provides a balanced and varied diet. Further benefits derive from its low content of saturated fatty acids, its richness in antioxidants as well as complex carbohydrates and fiber. Its positive effects are so well-known that scientists have linked the diet to a lower incidence of diseases such as cancer or cardiovascular disease, resulting in a longer life expectancy.

The Mediterranean diet embraces all the peoples of the Mediterranean, and its rich variety of landscapes, crops, farming techniques, markets, culinary expressions, flavors, perfumes, gatherings and celebrations, legends, innovation and tradition. It has evolved; incorporating new foods wisely, fruit of its strategic location and the capacity of Mediterranean people for mixing and exchanging. The Mediterranean diet is still an evolving, dynamic and vital cultural heritage.

Urban Growth

Today, cities around the world grow steadily, and urbanization process gets progressively faster all around the planet. Nowadays, there is more urban population than rural population and everything suggests that in 2050 more than 70% of the world population will live in cities. But, what makes people to migrate to big cities?

Urban growth comes mostly from the exodus of the rural population. Progressive degradation of the living conditions in rural areas contrasts with cities' strong attraction, where more job opportunities, a large concentration of economic investment, a large number and variety of services and numerous cultural and technologic exchange centers are usually offered.

City growth has generated the so-called urban agglomerations, which comprise areas surrounding a big city. These urban agglomerations may have extensions that cover a metropolitan area, grouping a city and the urban zone surrounding it into a megalopolis where the urban zone reaches hundreds of miles, such as New York or Tokyo.

Detective Novel

A detective novel consists of a kind of story where the narration of a crime is told. The basic structure of this kind of narration is that once a mysterious and inexplicable crime has happened, a clever detective investigates the case, thoroughly analyzing the facts and their circumstances, finally finding the solution. Detective novels enjoy a huge popularity, especially among young urban readers. But, why are detective novels more interesting for young and urban readers?

The interest in detective novels among this population sector is in keeping with the tension and intrigue throughout the whole text, concluding with a surprising and unexpected ending. In addition, detective novels are clearly urban and the main character is usually a young, brave and dynamic person with strong sex appeal. Young readers usually identify themselves with the investigator, experiencing vicariously the inquiries that reconstruct the crime until the murderer is found.

The detective novel is distinctly urban and it was born along with the security forces in European and North American cities in the early nineteenth century. In detective novels, the main characters –the detective, the murderer or the informer- are usually static; they don´t evolve along the story. Edgar Allan Poe is considered as the father of the detective novel and he is the creator of the first fictitious detective, Auguste Dupin, who inspired the very famous Sherlock Holmes.

Test text: insomnia.

Insomnia is a common sleeping disorder. One in three adults usually suffers some troubles while sleeping. People who suffer from insomnia have difficulties falling asleep, staying asleep, or both. As a consequence, they sleep very little, badly or discontinuously. That's the reason why they feel tired when they wake up. But, which are the causes of insomnia?

Several types of factors are responsible for this. There are environmental factors such as noise, light and heat changes. Unhealthy habits such as smoking, drinking alcohol or exciting drinks also contribute. In addition, there are some physiological factors, such as respiratory problems, chronic pain or reactions to certain drugs. Finally, there are psychological factors, caused by the concern about work, family, exams, health or personal problems.

Lack of sleep may interfere with the ability to work, the quick reflexes –e. g., driving, intellectual and concentration skills, and general wellbeing feeling. When insomnia is persistent, it is appropriate to consult a doctor because lack of sleep can lead to the abuse or inadequate use of drugs or even alcohol, which can increase or lengthen the problem.

Test text: The greenhouse effect

The greenhouse effect is a phenomenon by which the gases found in the atmosphere retain the heat emitted by the Earth. This heat comes from the natural solar radiation, but when it bounces on the earth's surface it is trapped by the gas barrier. When these gases stay between soil and atmosphere, the effect produced on a planetary scale is very similar to that of a greenhouse. The greenhouse effect is the main cause of global warming. But why does not the heat escape from the atmosphere?

The gases that retain heat are mainly carbon dioxide and methane. These gases have existed since the origins of the Earth. But its presence in the atmosphere began to multiply during the Industrial Revolution, at which time technological advances forced the use of fossil fuels. Since then, this dynamic has only increased, reaching 35% more carbon dioxide than at pre-industrial levels.

Some of the gloomy predictions about the future of civilization on Earth made by climatologists are, for example, the melting of polar ice caps, rising sea levels, deforestation, desertification, hurricanes and typhoons, drought, which will lead to the scarcity of food and wars over land, for drinking water and for natural resources. We must review our energy model, invest in renewable energy and better manage our energy resources.

6.3. Artículos publicados

A continuación, se adjuntan los estudios 1 y 2 de la presente tesis doctoral en su formato de artículo publicado. Ambos se adjuntan en sus versions originales en formato pdf en inglés.

Original Articles and Reviews

Age Differences in Eye Movements During Reading: Degenerative Problems or Compensatory Strategy?

A Meta-Analysis

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Abstract: We report the results of a meta-analysis of 22 experiments comparing the eye movement data obtained from young (M_{age} = 21 years) and old (M_{age} = 73 years) readers. The data included six eye movement measures (mean gaze duration, mean fixation duration, total sentence reading time, mean number of fixations, mean number of regressions, and mean length of progressive saccade eye movements). Estimates were obtained of the typified mean difference, *d*, between the age groups in all six measures. The results showed positive combined effect size estimates in favor of the young adult group (between 0.54 and 3.66 in all measures), although the difference for the mean number of fixations was not significant. Young adults make in a systematic way, shorter gazes, fewer regressions, and shorter saccadic movements during reading than older adults, and they also read faster. The meta-analysis results confirm statistically the most common patterns observed in previous research; therefore, eye movements seem to be a useful tool to measure behavioral changes due to the aging process. Moreover, these results do not allow us to discard either of the two main hypotheses assessed for explaining the observed aging effects, namely neural degenerative problems and the adoption of compensatory strategies.

Keywords: eye tracking, aging, multivariate meta-analysis, neural degenerative problems, compensatory reading strategies

Recent research has highlighted the fact that people's eye movement patterns during reading change with age (e.g., Rayner, Yang, Schuett, & Slattery, 2013). In particular, comparisons have been made between two age groups, commonly known as young adults and older adults, to quantify these changes. The main results of these comparisons are consistent with the view that the aging process results in a number of physiological and/or pathological changes consistent with visual and cognitive deterioration. Despite these difficulties, older adults seem to marshal a set of compensatory cognitive strategies in order to minimize the effects of aging on the reading process.

Eye movement patterns that people make when they read have been studied for a long time in order to test theories of what is seen, what is comprehended, and what is remembered about what has been read (e.g., Just & Carpenter, 1976; Rayner & McConkie, 1976). All three components of reading can presumably be related to observable eye movement patterns, which differ across age. For example, some differences can be related to changes in visual acuity and visual perceptual abilities that tend to deteriorate as people get older (e.g., Dowiasch, Marx, Einhäuser, & Bremmer, 2015). Research on visual changes with age has shown that saccadic latencies increase with age, and while reading, older persons tend to make more regressions and more and longer fixations (e.g., Rayner et al., 2013). Therefore, the present study begins with the idea that eye movements can be a good indicator of the changes that occur with advancing years in cognitive processes, and more specifically in reading, and ends with suggestions of some plausible explanations for the observed changes in reading patterns related to aging. Thus, this work aspires to be an informative synthesis in order to understand how our visual capabilities tend to deteriorate as we get older, focusing on the observation of any degenerative as well as compensatory behaviors manifested in the eye movements that people make while they are reading.

Whereas most saccadic movements proceed from left to right during normal reading, the reverse is true in 10% to 15% of the cases. Such saccades are called *regressions* (Rayner, 1998), which consist of saccades that move from right to left during reading in the same line or even jump to a previous line in the text. Moreover, regressions can be even larger than the typical forward saccade (more than

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10 previous character spaces on the same line or even to previous lines), which could mean that readers have not understood the text. In such cases, competent readers are very precise, sending their eyes to the part of the text which they did not understood, while poorer readers usually go further back than necessary in the text while they are looking for information that reduces the uncertainty (Murray & Kennedy, 1988). On the other hand, fixations that occur at the beginnings and ends of each line do not exactly land on the first and last letter of that line, and the initial fixation is typically longer (Rayner, 1977) than any other made along the same line. Also, the final fixation is typically the shortest one of all. Similarly, readers almost never fixate on blank spaces between words in a line.

Regarding the comparison of reading eye movements between young and older adults, there are several differences that consistently appear in the literature. Specifically, older readers make more fixations while reading (Rayner, Castelhano & Yang, 2009, 2010), and these fixations are also longer than those made by young adults (Rayner, Yang, Castelhano & Liversedge, 2011). Older adults also tend to have longer saccades and tend to skip more words than young adults (Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006; Rayner et al., 2009). In addition, older readers tend to make more regressions to missed words than younger ones, and older adults read more slowly than young adults, as they generally dedicate more time to read the same amount of text (Stine-Morrow, Miller, & Herzog, 2006). Therefore, while eye guidance and fixation disparity may improve with maturation into earlier adulthood, poor saccadic control and increased fixation disparity may reemerge in later stages of life and become relevant aspects of difficulties experienced by older readers (Kliegl, Grabner, Rolfs, & Engbert, 2004; Rayner et al., 2006, 2009; Stine-Morrow et al., 2006).

Several explanations for age-related differences in cognition have been applied to previous research in word identification, word naming, and reading. Although older readers generally read more slowly than younger readers, in many other aspects, their reading may be similar to that of younger readers (e.g., Rayner et al., 2006). Some authors have related age differences in reading ability with diminished working memory capacity, since older readers' working memory capacities are less than those of younger readers (e.g., Miller & Stine-Morrow, 1998; Risse & Kliegl, 2011; Stine-Morrow, Loveless, & Soederberg, 1996). These authors have also found that older adults appear to allocate more processing resources to the integration of new concepts as they are introduced in a text, whereas young adults tend to wait until the end of the sentence to integrate the new concepts. Miller & Stine-Morrow (1998) attributed this pattern to an attempt to compensate for age-related differences in working memory capacity.

A complementary, qualitative explanation for age differences in reading was suggested by Rayner et al. (2006, 2009, 2014), who argued that older readers might adopt some kind of specialized reading strategy to compensate for their slower reading and/or their age-related limitation in working memory capacity. For example, they might adopt a "riskier" reading strategy (Rayner et al., 2006, 2009, 2014). Specifically, older readers might rely more heavily on partial visual information (perhaps from parafoveal vision), or they might rely on frequency and predictability information to effectively skip more words in the sentences. Given their extensive experience with reading text, they might be willing to make more guesses about what upcoming words in the text are likely to be, more so than younger readers. In this case, there would be qualitative differences between the eye movement behaviors of older and younger readers.

At this point, it is possible to highlight and synthesize the main explanations given in the literature and reduce them to two main hypotheses which attempt to explain age-related differences in eye movement patterns between young and old readers. On the one hand, differences in eye movement patterns across age groups can be due to *changes produced by degenerative problems*. This consideration is supported by the fact that visual abilities decline with normal aging, and older adults experience a range of subtle visual deficits that could affect their resolution of the spatial frequency contents of words during reading (e.g., Elliot, Yang, & Whitaker, 1995; Owsley, 2011). It is also true that older adults show increases in the frequency and size of fixation variabilities compared to younger adults in ophthalmological assessments (e.g., Zaroff, Knutelska, & Frumkes, 2003). Thus, eye movement studies should be useful in measuring changes that occur in the way people read as they age, begging the question of whether these changes are solely produced by aging or additionally accentuated by degenerative visual problems. For example, a progressive change in visual abilities occurs with normal aging and appears predominantly as a decline in sensitivity for detailed visual information (e.g., Elliot et al., 1995; Owsley, 2011). This loss of sensitivity to information supplied by higher spatial frequencies is widely attributed to a combination of optical changes and changes in neural transmission with increasing age, but the precise effects of these changes on older adults' reading abilities are unknown.

On the other hand, differences in eye movement patterns across age ranges can be due to the *use of different reading behaviors as compensatory strategies*. The data might reflect a supplementary or compensatory strategy that older readers use to maximize their reading speed despite age-related declines in visual processing – a so-called risky reading strategy (O'Regan, 1990). Older readers might make use of preceding context and partial parafoveal information to make hypotheses about upcoming text, leading them to make longer saccades and skip over information more often than younger adult readers, but also resulting in more regressions when their guesses are incorrect. This proposed guessing strategy is especially "risky" given that there is evidence from nonreading tasks that older readers are less effective at processing nonfoveal information (Ball, Beard, Roenker, Miller, & Griggs, 1988; Sekuler, Bennett, & Mortimer Mamelak, 2000). In reading, this translates to a reduced perceptual span in older readers, which extends only about one word to the right of fixation (Rayner et al., 2009; but see Risse & Kliegl, 2011). Older readers are not only likely to make use of a smaller region of text on each fixation, but their perceptual spans are also more symmetric around the point of fixation, such that older readers rely less on the words to the right of fixation than young adult readers. Perhaps, it is not surprising then, given their reduced processing of nonfoveal information and smaller perceptual spans, that older readers also show attenuated preview benefits from the word to the right of fixation (Rayner et al., 2010; but see Risse & Kliegl, 2011). In summary, older adults not only process information from a reduced perceptual span in any given fixation, but they also are limited in the amount of information that they can process from parafoveal vision. These results are often interpreted as signs that older adults have greater difficulty in processing visual inputs while reading, thus prompting the adoption of a "riskier" reading strategy in order to compensate for poorer text processing by attempting to determine word identities as early as possible on the basis of partial word information (e.g., Rayner et al., 2006, 2009). In addition, older adults probably make more use of world knowledge and top-down processes in reading than younger readers do. They have greater linguistic and world knowledge that accrues from habitual engagement with text throughout adulthood, and such knowledge might serve as buffers against the effects of sensory decline in later years (e.g., Stine-Morrow et al., 2006). This hypothesis seems to be consistent with the evidence that despite some perceptual and working memory difficulties, older readers maintain a similar level of reading comprehension when compared with younger adult readers (e.g., Paterson, McGowan, & Jordan, 2013a; Rayner et al., 2010).

Even though there are dozens of studies of eye movement differences between younger and older readers, until now no meta-analysis has been performed to synthesize the evidence for differences in reading eye movements between different age groups. It is necessary to highlight that it is out of scope of the present meta-analysis to solve the open issue and to offer evidence of any or both of the hypotheses described above, namely neural degenerative problems and the adoption of compensatory strategies. Thereby, the main objective of this study is to offer an integrative and quantitative review of these differences in reading eye movements between young and older adults, using meta-analytic techniques. Thus, the principal contribution of the present meta-analysis will be to provide important information on the stability and the homogeneity of age-related eye movement patterns across the literature, which would hopefully help to solve the controversy between degeneration and compensation hypotheses in the long term.

Method

Selection of Studies

A search was conducted using a variety of methods. First, we searched the resources PsycINFO, PubMed, Medline, Web of Knowledge, and Google Scholar. The keywords for the search (both in English and Spanish) were all combinations among *eye movements/eye tracking, age differences/children/adults/younger adults/older adults, reading comprehension,* and *reading*. Second, we searched the relevant databases of two university libraries (Universidad Autónoma de Madrid and University of Leiden) using the same search terms. Finally, we contacted the authors of the papers recovered via e-mail to ask for any new studies, papers in press, or other sources of additional data. These searches yielded a total of 61 documents, but the final sample of studies used here was composed of 19 papers, totaling 22 experiments.

The following were the inclusion and exclusion criteria (see Figure 1):

1. They report empirical data, not simulated data.
2. The stimuli employed for the eye movement tasks were in English or Spanish.
3. The experiments were performed in 1990 or later. Experiments had to have been published after 1990, in order to achieve reasonable homogeneity in the technology used to record eye movements.
4. The experimental participants differed in studies performed by the same authors.
5. They included eye movement measures analyzed in the present meta-analysis (see below).
6. The experimental stimuli were written text, and the analyses were done at the paragraph, sentence, or word level at a minimum (word level was included because we consider the ways in which people recognize individual words to be important for reading).
7. The authors reported sufficient statistical information to compute effect size indices: means and standard deviations, *t*-tests, or *F* tests with one degree of freedom in the numerator.

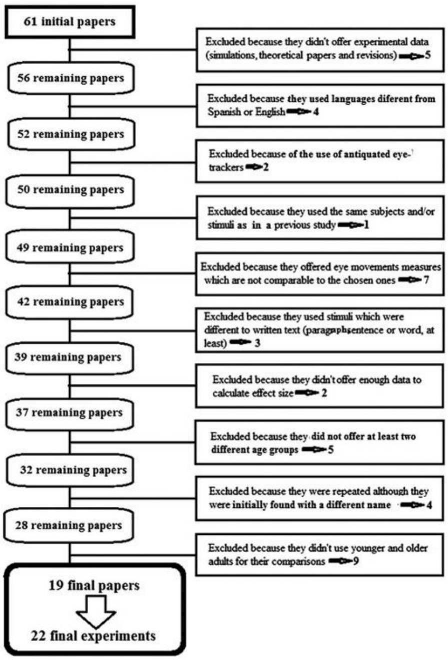

Figure 1. Flowchart (inclusion and exclusion criteria).

8. They reported data from at least two different age groups, two of them being from our targeted age populations.

The two age groups employed in the comparisons were young adults (average of the mean ages = 21 years; range: 19–24) and old adults (average of the mean ages = 73 years; range: 69–78). Table 1 specifies the studies finally included, along with the mean subject ages and their sample sizes.

Selection of Eye Movement Measures and Data Extraction

First, the eye movement measures from each study were extracted, along with the definitions of the measures provided by the authors. Second, the eye movement measures were grouped into broad general categories. Subsequently, all authors' definitions were checked, and, in agreement with a group of experts, the measures considered as homogeneous were pooled. Then, new definitions were agreed upon by the experts for any new groups of measures. Finally, based on all the above and the number of results available for each measure, we decided to keep six of the most relevant measures, as they also were the ones most frequently provided in the studies, and they offered a broad view of the eye movement data that usually characterize age group differences. Further, they all pertained to the general categorization of measures based on frequency or duration (measured in milliseconds). Regarding the text-level analysis, it is noteworthy that these eye movement measures were extracted in both single- and multiple-word levels and were not averaged in any case. Each of the measures in the present study is shown in their original text level of analysis. It also is worth highlighting that 5 of the 22 experiments included in the present study employed single-word-level analyses, and 17 reported data from multiple-word levels.

The proposed definitions for the six measures considered here were (see Hyönä, Lorch, & Rinck, 2003):

1. *Mean fixation duration* (mean time): average length of all fixations on a word, phrase, or target region, including re-fixations made at any time during reading, prioritizing the most complex structure (text > paragraph > sentence > word); measures at the character level were never included.
2. Gaze duration (mean time): average length of all fixations on a word, phrase, or target region, before the eyes moved from it the first time, or before the gaze crossed the right bound or, failing that, if either of the above did not appear, the duration of the first fixation on a word, phrase, or target region.
3. *Mean sentence reading time* (mean time): total length of the fixations on a target sentence that was syntactically and grammatically complete.
4. *Mean number of fixations* (mean frequency): average number of fixations in all the words, sentences, or target regions.
5. *Mean number of regressions* (mean frequency): average number of all regressions on all the words, sentences, or target regions, in which a regression was defined as any eye movement from a given point to an earlier point in the text (presumably read), being a word, sentence, or target region.
6. *Progressive saccade length* (mean frequency): average length of eye movements forward from the current point to a later point in the text, as measured by the number of character spaces between them. When available, the means, standard deviations, and sample sizes were taken from the original report. If these descriptive measures were not available, the t or F statistics were used. In those cases, in which data from more than one group were available (either of different ages within each of the two comparison groups, or different experimental conditions), weighting formulas were employed to estimate single means and

Table 1. Main descriptive statistics from the studies included in the meta-analysis

Studies	Age_Y	Age_O	N_Y	N_O	FD	GD	MSRT	MNF	MNR	PSL
Kemper et al. (2004) E1	19.7	75.2	10	10	0.48	0.11				
Kemper et al. (2004) E2	19.7	75.0	16	16	0.00	−0.01				
Kliegl et al. (2004)	21.9	69.9	33	32	0.76	0.74				
Kemper & McDowd (2006)	19.8	75.3	35	49	0.50	0.32	0.54			
Rayner et al. (2006)	23.9	77.5	16	16	0.34	0.47	0.56	0.43	0.87	
Kemper & Liu (2007) E1	20.5	72.8	39	29	0.72	0.90				
Kemper & Liu (2007) E2	19.8	76.1	30	32	1.33	1.08				
Kemper et al. (2008)	22.2	73.4	24	24	0.84	1.37				
Rayner et al. (2009)	22.8	73.1	24	24	0.54		0.44	0.45	0.96	0.05
Rayner et al. (2010)	20.8	72.3	36	18		0.30				
Rayner et al. (2011)	21.8	72.3	32	32	0.12	0.31	0.83	1.02	0.56	
Risse & Kliegl (2011)	23.0	71.0	40	40		0.23				
Paterson et al. (2012) E1	22.0	69.0	16	16	2.65			−1.27	1.10	3.57
Paterson et al. (2012) E2	21.0	69.0	16	16	0.55			−0.97	0.00	5.52
McGowan et al. (2013)	19.0	72.0	16	16	1.72	0.16	2.50	1.81	5.35	3.98
Paterson et al. (2013a)	21.0	73.0	12	12	1.71		0.57	0.57	2.96	5.55
Paterson et al. (2013b)	22.0	69.0	16	16	0.16	−0.69	2.82	2.97	5.20	5.13
Rayner et al. (2013)	21.3	77.8	16	8	2.03	1.58	2.13	1.11	5.14	3.50
Stites et al. (2013)	20.4	69.5	18	18	1.04	0.84				
Jordan et al. (2014)	21.0	69.0	16	16	3.70			−2.26		
Rayner et al. (2014)	21.3	77.6	16	16	3.45		2.49	1.26		1.29
McGowan et al. (2015)	19.9	72.5	15	15	2.54	1.01	3.28	1.76	5.72	5.19

Notes. The first columns show the average age and the sample size of the groups of old and young adults compared. The six columns to the right show the effect size (Cohen's *d*) calculated for each measure obtained from each of the studies included in the meta-analysis (FD = mean fixation duration; GD = gaze duration; MSRT = mean sentence reading time; MNF = mean number of fixations; MNR = mean number of regressions; PSL = progressive saccade length); E1 = Experiment 1; E2 = Experiment 2.

variances. When several experimental conditions were included in the design, our choice always included the control group, as it represented the condition closest to natural reading. When there was no control condition, we always included the condition with the more general task (closest to natural reading). In other cases, the results from several experimental conditions were averaged.

Effect Size Calculation and Statistical Analysis

Given the design of the experiments and the format of the statistics provided, our choice for an effect size measure was the standardized mean difference,

$$d = (\bar{X}_O - \bar{X}_Y)/\hat{S}_{pooled}.$$

The standard deviations were obtained by pooling those from the samples. The order of the means in the numerator was due to the expectation of larger values for old adults than for young adults (longer times and higher frequencies), so that positive values were expected. That is, positive values of d reflected higher means in the older samples, whereas negative values reflected higher means in the younger samples. The d values were corrected for bias due to small sample sizes according to Hedges' (1981) formula (Borenstein, 2009; Botella & Sánchez-Meca, 2015). This correction is recommended in cases in which Cohen's formula uses the maximum likelihood estimator for the variance, which is biased with small sample sizes. The effect size values of each measure from each study are shown in the six columns on the right in Table 1.

Combined estimates of the effect sizes were obtained separately for each measure, weighting each estimate by the inverse variance method, $d_\bullet = \sum w_i \cdot d_i / \sum w_i$ (where $w_i = 1/\hat{S}_i^2$, and d_i is the effect size of each study; Borenstein, 2009; Borenstein, Hedges, Higgins, & Rothstein, 2010). The heterogeneities of the estimates were analyzed by Q tests and I^2 indexes (Huedo-Medina, Sánchez-Meca, Marín-Martínez, & Botella, 2006). Statistical analyses assumed a random-effects model that is generally preferred because it is more conservative than a fixed-effect model and allows generalizing conclusions beyond the specific set of studies analyzed (Borenstein et al., 2010; Hedges & Vevea, 1998; Raudenbush, 2009). The method used to estimate between-study variability was the Hartung-Knapp-Sidik-Jonkman method for random-effects meta-analysis

Table 2. Combined estimates for the six eye movement measures with a random-effects model (significance tests with the Hartung-Knapp-Sidik-Jonkman method; IntHout et al., 2014)

Measure	*k*	*d*	95% CI	*t* (*p*)	*Q* (*df*)	I^2
FD	20	1.19	[0.69, 1.69]	5.00***	112.39 (19)***	89%
GD	16	0.54	[0.25, 0.82]	3.95**	40.14 (15)***	65%
MSRT	10	1.55	[0.75, 2.35]	4.38**	64.66 (9)***	89%
MNF	12	0.56	[−0.36, 1.49]	1.35	124.75 (11)***	93%
MNR	10	2.69	[1.03, 4.35]	3.66**	137.85 (9)***	96%
PSL	9	3.66	[2.14, 5.18]	5.56***	142.54 (8)***	92%

Notes. FD = mean fixation duration; GD = gaze duration; MSRT = mean sentence reading time; MNF = mean number of fixations; MNR = mean number of regressions; PSL = progressive saccade length. *k* = number of studies analyzed in each measure; *d* = mean effect size. $^{**}p < .01$; $^{***}p < .001$.

(IntHout, Ioannidis, & Borm, 2014). Calculations with this method were performed using R statistical software (version 3.3.2; R Development Core Team, 2016) with the Metafor package (Viechtbauer, 2010a, 2010b) for the standardized mean effect size, the *Q* statistic, and the I^2 statistic estimates. An individual meta-analysis was performed with this method for each one of the eye movement measures reported in the present study.

Moderator Variables

In order to analyze the heterogeneity between the results of the studies, moderator analyses were carried out for each of the eye movement measures. Five moderator variables were selected based on their potential explanatory role in the results of the analyzed studies and their availability in the presented data. The variables included (1) the sampling rate in cycles per second of the eye-tracking apparatus (60 Hz, 250 Hz, 500 Hz, and 1,000 Hz), (2) the accuracy of the eye-tracking apparatus, based on the different sampling rates, but separating the highest rate from the others (i.e., classifying them as Medium for the cases from 60 Hz to 500 Hz and High for the cases with 1,000 Hz), (3) the difference between the mean ages of the younger and older adults (ranging from 47.0 to 56.5), (4) the average age of the older adult groups (ranging from 69.0 to 77.8), and (5) the text level of analysis employed in the studies (one-word-level or multiple-word-level).

Multivariate Meta-Analysis Approach

When multiple endpoints are analyzed independently, the probability of obtaining at least one significant result increases considerably. One way to avoid this problem is to use a conservative α value (e.g., 0.01 instead of 0.05). Another way consists of performing a multivariate combined analysis in which the endpoints are not independent, because the samples are the same (Gleser & Olkin, 2009a). We tried to do this with our data set, but it was not possible, as none of the studies offered values for all six measures. However, we employed a multivariate analysis for the combination that had a larger number of values available. Specifically, our database includes 14 studies that provided effect size estimates for the mean fixation duration and the gaze duration, simultaneously. We applied the Gleser and Olkin (2009a) procedure to this subsample of studies; to do this, we used the sintaxis for R statistical software (version 3.3.2; R Development Core Team, 2016) proposed and developed by the same authors (Gleser & Olkin, 2009b), which uses functions from the Metafor package (Viechtbauer, 2010a, 2010b).

Results

A summary of the results obtained for all measures is shown in Table 2. On the one hand, all combined effect size estimates showed values ranging from 0.54 to 3.66. Within the six analyzed measures, five of them reached *p*-values under .01, leading us to reject the null hypothesis of no age effect for those five measures. Mean number of fixations is the only measure for which the effect was not significant. The effect size had a positive sign in every case, indicating that the measures showed higher mean values for older adults than younger adults. Graphical displays of these results are shown in Figures 2–7 as forest plots for each of the six eye movement measures analyzed in the present study. On the other hand, all homogeneity tests showed values for the *Q* statistic with $p < .001$, leading us to reject the null hypothesis of homogeneity for all six cases. Thus, for all measures, there was a margin of variability which could be explained by the presence of some moderator variable.

In the same way, all values of the I^2 statistic were over 62%, indicating that the heterogeneity was higher than random variability for the six cases. Again, this variability could be due to the effects of some moderator variables beyond random error. Specifically, for all cases, considering the categories proposed by Higgins and Green (2011), the heterogeneity should be assessed as *considerable* (> 75%), with

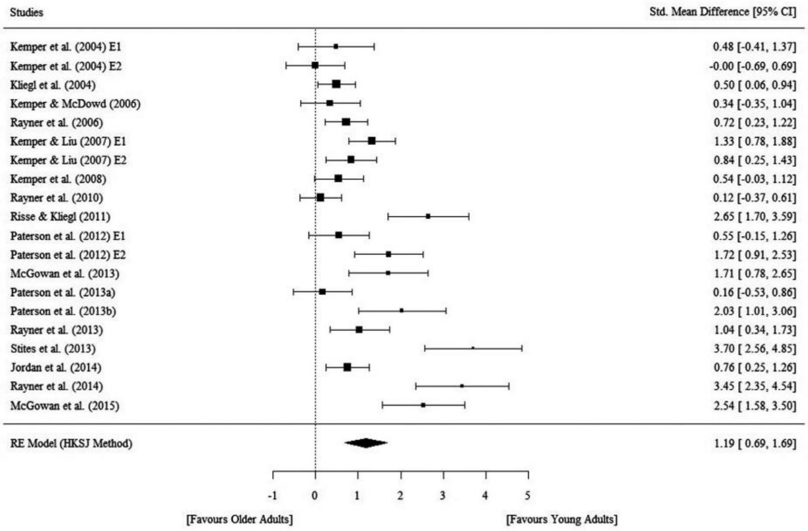

Figure 2. Forest plot of the mean effect sizes for the "*mean fixation duration*" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

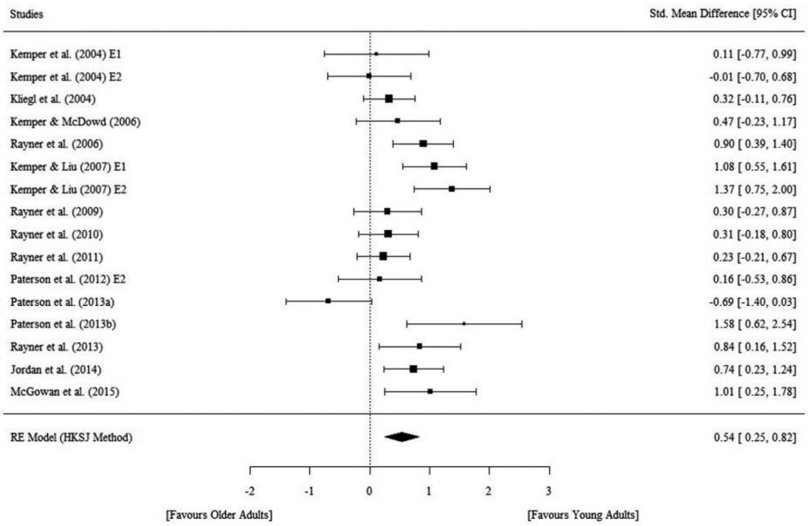

Figure 3. Forest plot of the mean effect sizes for the "*gaze duration*" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

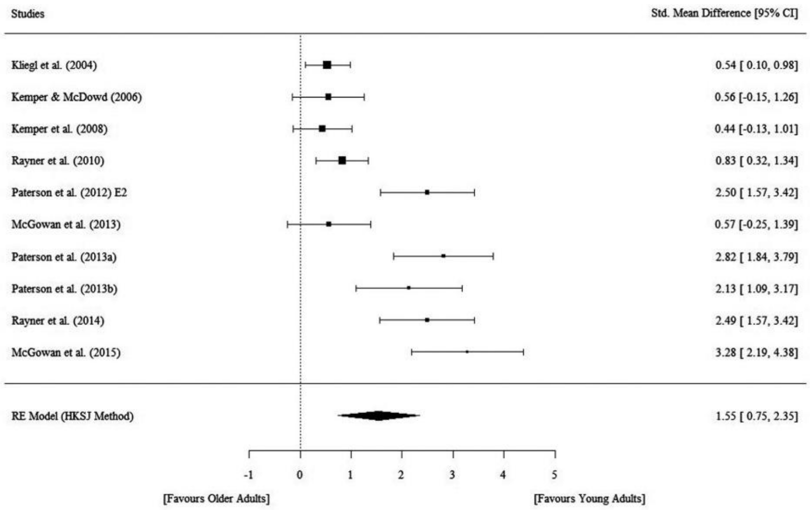

Figure 4. Forest plot of the mean effect sizes for the "*mean sentence reading time*" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

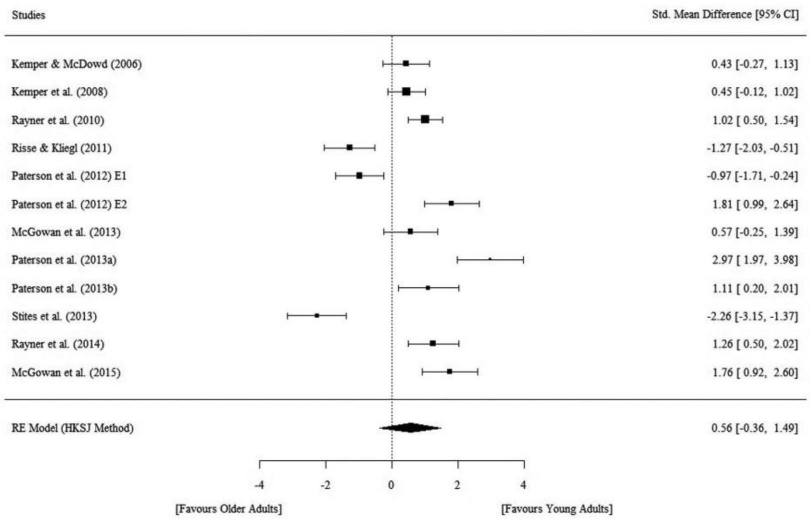

Figure 5. Forest plot of the mean effect sizes for the "*mean number of fixations*" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

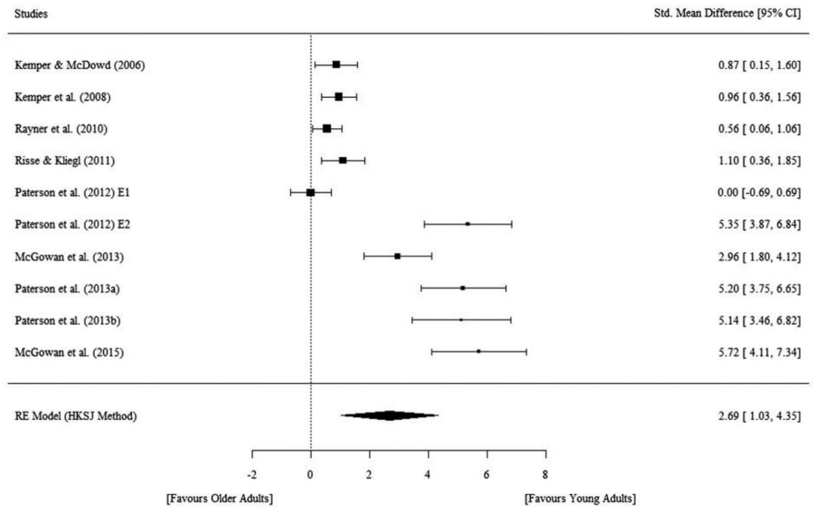

Figure 6. Forest plot of the mean effect sizes for the "*mean number of regressions*" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

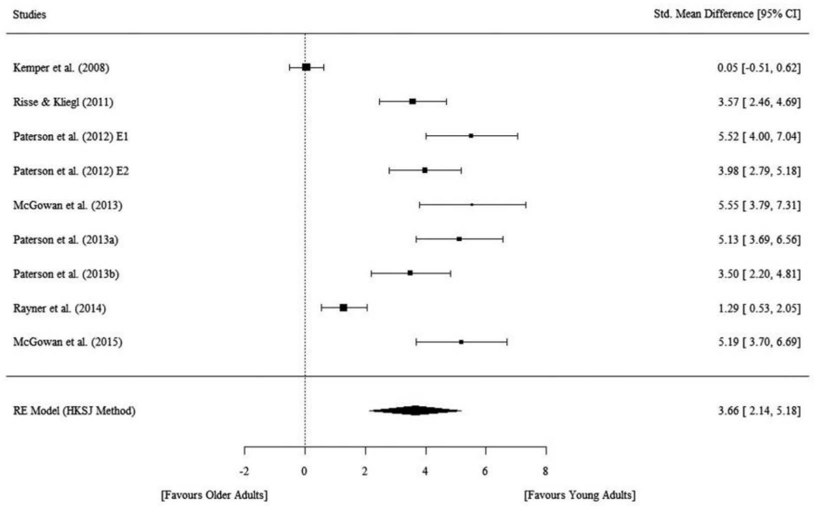

Figure 7. Forest plot of the mean effect sizes for the "*progressive saccade length*" measure, represented with the model estimates for the standardized mean difference and the 95% CIs of the older and young adult groups. Studies are ordered by publication date.

Table 3. Synthesis of the multivariate analysis for both measures: "mean fixation duration" and "gaze duration" with 14 studies

		Heterogeneity	Test results				
Correlation	Measure	Q_w (*df*)	*p*-value	ES	*SD*	*z*-value	*p*-value
.2	FD	76.761 (26)	< .001	0.738	0.084	8.748	< .001
	GD			0.586	0.083	7.057	< .001
.5	FD	75.371 (26)	< .001	0.730	0.084	8.672	< .001
	GD			0.583	0.083	7.016	< .001
.7	FD	85.271 (26)	< .001	0.714	0.084	8.488	< .001
	GD			0.575	0.083	6.931	< .001

Notes. Fixed-effect model. FD = mean fixation duration; GD = gaze duration.

only one exception, gaze duration, which has *substantial* heterogeneity (65%).

Moderator Analyses

Moderator analyses showed nonsignificant effects ($p > .05$) of the variables of text levels of analysis employed in the studies, the age differences between the groups, and the average ages of the older adult group for each of the six eye movement measures. Nonsignificant effects were also found for the sampling rate in cycles per second of the eye-tracking apparatus and the subsequent accuracy of the eye-tracking apparatus variables for gaze duration, mean number of fixations, and mean number of regressions ($p > .05$). In contrast to these results, statistically significant effects were found for two moderator variables: the sampling rate in cycles per second and the subsequent accuracy of the eye-tracking apparatus, for mean fixation duration, mean sentence reading time, and progressive saccade length ($p < .05$). These results showed significant differences in the estimates made for eye movement measures in the analyzed studies, based on the accuracy of the eye-tracking apparatus employed. The direction of those effects is that a larger accuracy is associated with larger effect sizes for the mean fixation duration, the mean sentence reading time, and the progressive saccade length measures. The complete set of estimates is included in Appendix.

Multivariate Analysis of Effect Size

In order to test the stability of the univariate meta-analytic results, we applied the Gleser and Olkin (2009a) multivariate procedure to the selected subsample of 14 studies. The results we obtained are shown in Table 3. The procedure requires the correlations between the means of both measures, but none of the 14 studies gave us those data. For that reason, we imputed three correlation values: .2, .5, and .7. As shown in Table 3, the results were not significantly modified by the assumed correlation values. In addition, the conclusions did not change when analyzing data with a multivariate model instead of a univariate model. For the mean fixation duration variable, there was a relevant change in the estimate (1.15 for the univariate and 0.73 for the multivariate with $r = .50$). This discrepancy might be due to the fact that the multivariate analysis includes only 14 studies in which data for gaze duration were also offered.

Discussion

Based on the synthesis of the results from 22 experiments analyzed in the present study, we provide estimates of the age differences found in the main measures for assessing eye movements during reading (Table 2). This meta-analysis adds substantial information to what is available in qualitative reviews of the existing literature; namely, it shows the combined effect sizes for each of the eye movement measures analyzed in the present study, and it also has the potential to identify sources of heterogeneity observed in these effects across studies. There is a substantial variation in effect sizes across the 22 experiments included in the meta-analysis, and there are variables that moderate the effects observed. The findings of this meta-analysis are generally consistent with findings from previous studies, which compare the reading performance of young and older adults. In general, most of the studies that have compared skilled young adult readers and older adult readers led to the conclusion that older adults tend to read more slowly, make longer fixations, longer saccades, more regressions, and skip words more often (e.g., Kemper, Crow, & Kemtes, 2004; Kliegl et al., 2004; McGowan, White, Jordan, & Paterson, 2013; Rayner et al., 2011). These conclusions are valid for nearly all the eye movement measures analyzed here, except for the "mean number of fixations" measure, whose combined estimate of the effect size did not reach a significant value. Therefore, we consider that these estimates can be informative, at least in order to confirm statistically the most common patterns observed in the literature, which have been described above. Thus, the present study offers an integrative vision of the state-of-the-art literature in the field. However, the current meta-analytic results do not allow us to discard either of the two main hypotheses for the observed aging effects, that is, neuronal degenerative problems associated with aging and the potential development of compensatory strategies. Since we do not yet have the critical methods with which to derive contrastive predictions from these two positions, we cannot discard either of them. One of the conclusions of our meta-analysis is that it seems most reasonable at present to maintain the idea that both hypotheses are supportable and might well form credible, compatible, and complementary explanations for the observed changes in eye movement behavior in reading that accompany advancing age.

It is assumed that some of the negative changes in visual processes produced by aging (e.g., neural degenerative problems) can be effectively reduced by activating other neurological or cognitive resources, as would be expected if compensatory reading strategies could be developed. Some authors have suggested that cognitive deficits in healthy older adults are largest for tasks that are highly dependent on executive control processes (such as working memory), because these processes are mediated by the prefrontal cortex (PFC), which is the region most disrupted by healthy aging (e.g., Cabeza et al., 1997). Furthermore, older adults often present a hemispheric asymmetry reduction (see the HAROLD Model, Cabeza, 2002). This view, also known as the "frontal lobe hypothesis," rests on the assumption that both cognitive aging and specific cerebral losses go hand in hand in reducing executive control functions in elderly persons. Compared to young adults, older adults show reduced activity in some brain regions but increased activity in other brain regions. Cabeza, Anderson, Locantore, and McIntosh (2002) describe the aging brain as a system that reorganizes its functions when necessary to compensate for certain losses due to reduction in neural capacities. However, greater activity is not always associated with better cognitive performance, and it is unclear whether increased activity in specific brain regions in older adults reflects compensatory strategies or merely attempts to deal with increasing task difficulty. It is also important to note that compensatory changes in the aging brain may not always reflect a net increase in brain activity, but rather an increase in functional connectivity. If older readers adopt a "riskier" reading strategy to compensate for their perceptual limitations in text processing by making more use of world knowledge and other top-down processes, this strategic change could be reflected in increased neural connectivity across brain regions. Although most functional neuroimaging studies of aging have focused on age effects on regional activity, there is evidence that functional connectivity is also modulated by aging, including increases in PFC connectivity (Cabeza et al., 2002). If age-related increases in PFC activity can be attributed to compensation processes, then it is possible that age-related increases in PFC connectivity could be also compensatory.

The current study can also help to address some issues in applied healthcare settings and the design of multimedia resources for the elderly. For example, knowledge about the use of different reading strategies and different cognitive activities unique to older adults would be very relevant for healthcare systems. Clinicians working with older adults in a variety of settings could incorporate such knowledge in promoting better mental health in older adults. Older adults reporting cognitive declines (such as reading difficulties) should undergo cognitive testing. Checking what distinguishes normal versus degenerative visual changes will enable clinicians to provide reassurance to most older adults that they are experiencing changes as a normal part of the aging process. Anticipatory guidance for older adults should be expanded to focus on cognitive as well as physical health. Research confirms the benefits of initiating new cognitive health activities targeting specific cognitive deficiencies, and relevant activities are now readily available using text, computer, and gaming technologies (Vance, McNees, & Meneses, 2009). Applications of studies of cognitive aging that could be directed to better diagnosis, prognosis, and care of elderly persons should be an important direction for future research given the gradual aging of our society.

Another applied setting that can be amenable to changes designed to go hand in glove with compensatory strategies for older readers are technological modifications of multimedia resources. Eye-tracking tools might play an important role in the design of materials or procedures for information presentation, such as in adapting to individual differences or changes in reader's goals. For example, Kostons, Van Gog, and Paas (2009) used replays of participants' own eye movement records as a tool to help them self-assess their task performance. Similarly, reading tools such as e-books could be tuned to the natural eye movement patterns of individuals and different age groups. Although words are composed from a small set of letters, words are actually complex visual stimuli containing a variety of spatial frequencies ranging from low spatial frequencies that may be useful for determining the overall layout of text, including the size, shape, and location of words, to high spatial frequencies that may help to identify specific letter features (e.g., Allen, Smith, Lien, Kaut, & Canfield, 2009). Consequently, if changes in visual abilities associated with normal aging lead to changes in the functionality of various spatial frequencies when reading, younger and older adults might well differ in their use of the spatial frequency contents of text, and this may have important consequences for understanding adult age-related changes in reading performance. This conclusion has important technological applications in the design of a variety of text display devices, such as smartphones, tablets, and e-books, in order to make their contents accessible to older readers and those readers with specific visual and cognitive disabilities.

We are aware of some limitations of the present study. A major determinant of the validity of the meta-analysis is the sample size of studies that are included in the analysis. This determines which analyses can be carried out, as well as the quality of the results and the conclusions that can be extracted. In the present case, the number of studies located was relatively small (especially for some of our measures). Research is limited because measuring differences in eye movement patterns across different age groups is a relatively recent research area, and it is difficult to tackle in that it requires very precise measurement instruments that are not always affordable or practical for use by investigative teams. Despite such sample limitations, it can be said with a good degree of certainty that the sample exhausts the present set of studies available on comparative research of eye movement patterns in young and elderly readers. However, the sample size was sufficient to satisfy the general requirements for the validity and reliability of the meta-analysis. Of course, given the correlational nature of meta-analysis, our study cannot demonstrate any causal relationships. Nevertheless, we have reached conclusions consistent with the major body of previous literature, and we have achieved in providing relevant information on the stability and the homogeneity of age-related eye movement patterns in reading, offering an integrative vision of the state-of-the-art literature in the field.

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Appendix

Table A1. Moderator analyses for the several eye movement measures employed

Measure	Moderator	*b*	95% CI	*t*
FD	Hz	0.001	[0.00, 0.00]	2.73*
	Accuracy	1.19	[0.37, 2.01]	3.04**
	Age difference	0.006	[−0.15, 0.17]	0.08
	OA average age	−0.01	[−0.19, 0.16]	−0.14
	Text level	−0.55	[−1.72, 0.61]	−0.99
GD	Hz	−0.00	[−0.00, 0.00]	−0.06
	Accuracy	0.05	[−0.59, 0.69]	0.17
	Age difference	0.05	[−0.05, 0.15]	1.11
	OA average age	0.07	[−0.05, 0.18]	1.27
	Text level	0.26	[−0.58, 1.09]	0.66
MSRT	Hz	0.002	[0.00, 0.00]	3.11*
	Accuracy	1.65	[0.61, 2.70]	3.66**
	Age difference	−0.00	[−0.31, 0.31]	−0.02
	OA average age	−0.09	[−0.40, 0.22]	−0.65
	Text level	1.31	[−0.19, 2.81]	2.01
MNF	Hz	−0.00	[−0.00, 0.00]	−0.03
	Accuracy	−0.09	[−2.33, 2.14]	−0.09
	Age difference	0.18	[−0.10, 0.46]	1.42
	OA average age	0.14	[−0.14, 0.43]	1.14
	Text level	1.54	[−0.23, 3.30]	1.94
MNR	Hz	0.003	[−0.00, 0.00]	1.79
	Accuracy	2.73	[−0.42, 5.87]	2.00
	Age difference	0.30	[−0.27, 0.87]	1.21
	OA average age	0.09	[−0.51, 0.68]	0.34
	Text level	1.69	[−1.95, 5.33]	1.07
PSL	Hz	0.008	[0.00, 0.01]	2.77*
	Accuracy	4.06	[0.59, 7.54]	2.77*
	Age difference	−0.16	[−0.62, 0.30]	−0.84
	OA average age	−0.28	[−0.74, 0.17]	−1.48
	Text level	−1.07	[−5.00, 2.86]	−0.64

Notes. FD = mean fixation duration; GD = gaze duration; MSRT = mean sentence reading time; MNF = mean number of fixations; MNR = mean number of regressions; PSL = progressive saccade length; *b* = estimate of the effect; Hz = the sampling rate in cycles per second of the eye-tracking apparatus; Accuracy = accuracy of the eye-tracking apparatus; Age difference = age difference between age groups, older and young adults; OA average age = average age of the older adult group; Text level = text level of analysis employed in the studies. $*p < .05$; $**p < .01$; $***p < .001$.

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Specific relevance instructions promote selective reading strategies: evidences from eye tracking and oral summaries

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Background: The present study analysed how relevance instructions affect eye movement patterns and the performance in a summary task of six expository texts.
Methods: Forty-one undergraduate students participated in the experiment; half of them were instructed to make an oral summary of the main ideas focusing on the 'why' question that appeared at the end of the first paragraph (specific relevance instruction), while the other half were instructed to make an oral summary of the main ideas of the text (general relevance instruction).
Results: Eye movement patterns revealed that specific instructions promoted more and longer fixations and more regressions for relevant information than general instructions. A higher percentage of words in the summary task related to relevant information was recalled when readers received specific instructions.
Conclusions: These findings suggest that relevance instructions influence how readers enact strategies to meet their reading goals and how these strategies are reflected on memory.

Keywords: relevance instructions, selective reading strategies, expository texts, eye movements, summary task

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Highlights

What is already known about this topic

- A reading goal is formed on the basis of the reader's personal intentions and given intentions, such as a given reading perspective.
- Readers modulate their attention to task-relevant content in response to specific task instructions.
- There are strong evidences showing that eye tracking offers useful and accurate data about online processes during reading.

What this paper adds

- The type of relevance instruction influences how readers enact strategies to meet their reading goals, and these strategies have an influence on memory.
- Readers who receive a specific relevance instruction show a strategic reading behaviour, which is also reflected in the quality of their recall.
- Readers who adopt a selective strategy tend to use it in a consistent way across different texts and topics.

Implications for theory, policy or practice

- There is a benefit in combining online and offline measures to examine the influence of relevance instructions on texts' strategic processing.
- The ability to distinguish relevant from irrelevant content in response to specific task instructions is an important instance of a competency that readers must develop in order to become efficient and effective as readers and learners.
- Assigning a comprehension perspective through relevance instructions should increase learning of perspective-relevant information from expository materials, such as textbooks.

Comprehending instructional texts is essential in educational settings. The educational psychology literature is replete of research from the 1970s and the 1980s intended to improve students' learning (e.g., Armbruster, 1984; Armbruster, Anderson, & Ostertag, 1987; Faw & Waller, 1976; Hamaker, 1986; Hamilton, 1985; Kantor, Anderson, & Armbruster, 1983; Peeck, 1970). During this period, many studies promoted theoretical explanations of the effects of state variables (e.g., prior knowledge, criterion task, length of the instructional texts and adjunct questions) and process variables (e.g., allocation of attention, encoding strategies and selective processes) with their main focus being on general learning and selective learning from texts (e.g., Anderson, 1982; Armbruster, 1984; Hamaker, 1986; Hamilton, 1985).

A common approach cited in much of this literature was to analyse the effects of adjunct questions on prose learning (e.g., Anderson & Biddle, 1975; Andre, 1979; Duchastel, 1983; Duchastel & Nungester, 1984; Hamaker, 1986; McGaw & Grotelueschen, 1972; O'Kon, 1988; Peeck, 1970; Reynolds & Anderson, 1982; Rickards, 1979). Adjunct questions are those that have been inserted into instructional texts to analyse their influence on what is learned. These adjunct questions, such as the why questions, have generally produced a positive effect on learning, called a 'forward effect' (Rickards, 1979). A forward effect consists of a change in the learner's processing strategy on subsequent text passages as guided by the type of question previously asked (O'Kon, 1988). Following Rickards (1979), the forward effect of adjunct questions can be classified into two types: a specific forward effect and a general forward effect. The specific forward effect is due to the learner's selective attention towards questioned material, whereas the general forward effect is due to an increase in the learner's overall attention to all information (Rickards, 1979). Each effect can produce different results in performance, depending on whether the test item was designed to measure learning of relevant or incidental material related to the question. More recently, Graesser and Lehman (2011) proposed the *focus assumption* model, supporting the specific forward effect by assuming that presenting a reader with a question will cause more attention to be devoted to question-relevant content than to content that does not pertain to the question. As a consequence, question-relevant information will be more likely to be encoded and remembered than incidental or irrelevant information.

Relevance instructions and their effects on text processing

Relevant information in a text can be determined from the perspective of the reader and from the pertinence of specific instructions. For example, Sperber and Wilson (1986) define relevance as a function of the reader's goals or interest in reading a text; from the perspective of the reader, it is what makes the text content worth reading. It is important to recognise the 'in situ' nature of relevance. Similarly, Lehman and Schraw (2002) define relevance as 'the extent to which text segments are germane to the reader's goal and purposes' (p. 738), suggesting that reading goals and purposes are two factors that determine the relevance of text segments. Thus, relevance can change across readers and across different contexts for the same reader. Whatever the source of relevance for a given reader in a given situation, relevance has critical implications for text processing. Readers can, in theory, attend more fully (Kaakinen & Hyönä, 2005; McCrudden, Magliano, & Schraw, 2010) or more efficiently (McCrudden, Schraw, & Kambe, 2005) to relevant information, improving its comprehension and memory relative to less relevant information.

Despite the fact that most theories of comprehension do not account explicitly for text relevance, there has been considerable research on interventions that could be construed to be instances of relevance instructions (e.g., Kaakinen, Hyönä, & Keenan, 2003; Lorch, Klusewitz, & Lorch, 1995; Lorch, Lorch, & Mogan, 1987; Narvaez, van den Broek, & Ruiz, 1999). These studies often involve a prereading instructional set (e.g., read to summarise) or concurrent reading activity (e.g., answering adjunct questions) that directs the readers to specific dimensions of the text. This research has consistently demonstrated that the specification of a reading goal has overarching effects on how readers process texts. For instance, McCrudden and Schraw (2007) conducted an extensive literature review of research on the role of relevance instructions in text learning. They identified two main categories of relevance instructions that researchers have used individually or in combination: the general and specific relevance instructions (see McCrudden, Magliano, & Schraw, 2011, for a review).

General relevance instructions prompt readers to use a broad frame of reference while reading (e.g., read for comprehension and read to be able to summarise the main ideas of the text). Such purpose instructions provide readers with a general reason for reading that may influence the types of processing in which they engage, such as influences on the types of inferences made (van den Broek, Lorch, Linderholm, & Gustafson, 2001; van den Broek, Risden, & Husebye-Hartmann, 1995). There are several empirical demonstrations that manipulations of general relevance instructions have systematic effects on the readers' processing and memory for text (Kaakinen & Hyönä, 2007, 2008, 2011; Lorch et al., 1987; McCrudden et al., 2005; Narvaez et al., 1999; Rothkopf & Billington, 1979; van den Broek et al., 2001). There is also evidence suggesting that different mechanisms may underlie the effects of perspective instructions and purpose instructions. For readers possessing appropriate background knowledge, perspective instructions help them to distinguish particular content as being more or less relevant to the perspective. For example, in reading a description of the interior of a house from the perspective of a homebuyer, features such as room layout and size are relevant and should receive more attention; in reading the same text from the perspective of a burglar, the objects in the house are more relevant than the structural features of the house. Indeed, the two perspectives lead to systematic differences in what readers attend to while reading that, in turn, influences what they remember from the text (Kaakinen et al., 2003; Kaakinen, Hyönä, & Keenan, 2002; Pichert & Anderson, 1977). In contrast, purpose instructions (e.g., read to comprehend and read for entertainment) appear to affect the types of processing in which readers engage. When reading to comprehend is compared with reading for entertainment, readers in the former case process text more carefully and construct a more coherent text representation (Lorch et al., 1995; Lorch, Lorch, & Klusewitz, 1993; van den Broek et al., 2001). Thus, whereas perspective instructions confer differential relevance on text content, purpose instructions seem to operate by affecting the relevance of different processes during reading.

Despite several findings that general relevance instructions affect how readers process texts, such instructional manipulations do not always produce unambiguous effects on text processing (Graesser & Nakamura, 1982; Zwaan, Magliano, & Graesser, 1995). General instructions are often open to alternative interpretations; readers receiving the same instruction may develop different goals and use different strategies to reach those goals (McCrudden et al., 2010). For example, instructions to generate a summary of a text might lead to several different outcomes. Some readers might produce syntheses of the main ideas of the entire text; other readers might produce lists of explicit statements from the text; still other readers might include their opinions or evaluations of the text (León & Escudero, 2015).

Specific relevance instructions state reading goals that target a subset of text content as relevant. Specific relevance instructions are typically less ambiguous than general relevance instructions and therefore more consistently interpreted by readers. Specific relevance instructions include targeted text segments and elaborative question instructions (McCrudden et al., 2011). For example, a specific relevance instruction might be an elaborative 'why' question intended to prompt readers to integrate specific segments across paragraphs and/or with prior knowledge (e.g., how did the Thames River become so contaminated?). Specific relevance instructions can take many forms, including prereading questions/objectives (i.e., presented to readers before they begin reading), prequestions (i.e., inserted before and pertaining to upcoming segments), and postquestions (i.e., inserted after and pertaining to previous segments).

According to the *goal-focusing model* (McCrudden et al., 2010; McCrudden & Schraw, 2007), a reading goal is formed on the basis of the reader's personal intentions and given intentions, such as a given reading perspective. Text information is then processed in order to meet the reading goal with the result that relevant information is given priority over information that is not relevant to the reading goal. According to the framework of *perspective-driven text comprehension* (Kaakinen & Hyönä, 2008), perspective instructions activate relevant concepts in the reader's knowledge base. These concepts receive preferential status during text processing. In sum, several researchers propose various mechanisms by which text content may be processed selectively depending upon the relevance of the content to the reader's goal. Selective processing seems more likely and appropriate in the context of specific relevance instructions than in the context of general relevance instructions (McCrudden et al., 2010).

These processing differences due to different types of relevance instructions should be reflected on the way readers inspect a text. There is empirical evidence from studies that analyse sentence reading times that readers modulate their attention to task-relevant content in response to specific task instructions. For example, competent adult readers pay more attention to topic-introducing sentences (Goldman & Saul, 1990; Lorch et al., 1987; Lorch, Lorch, & Matthews, 1985) when they read to comprehend. Moreover, throughout the last years, the eye tracking methodology has been applied to investigate many different issues related to reading (e.g., Rayner, 1998), and this technology has been also used to investigate text-processing strategies (e.g., Blanchard & Iran-Nejad, 1987; Hyönä & Lorch, 2004; Hyönä, Lorch, & Kaakinen, 2002; Rothkopf, 1978; Vauras, Hyönä, & Niemi, 1992; for individual differences in local reading strategies, see Olson, Kliegl, Davidson, & Foltz, 1985).

The aim of this study was to analyse the effects of general and specific relevance instructions on the online processing, measured with eye movement data, and the offline processing, measured with an oral summary task, of question-relevant text information. In the present study, participants read six different expository texts while their eye movements were tracked and generated an oral summary related to the contents of the passage and also to a why question located at the end of the first paragraph after reading each text. Half of the participants received specific relevance instructions in order to summarise paying special attention to the why question; half received general relevance instructions in order to summarise the main contents of the texts. The why question was always located in every text at the end of the introductory paragraph in both conditions.

We applied eye tracking methods to analyse the influence of relevance instructions on the processing of question-relevant and question-irrelevant text sections. There are strong evidences that show that eye tracking is a useful method to examine online processes during reading, offering accurate data about the time course of text processing (e.g., Hyönä et al., 2002; Kaakinen et al., 2002; Kaakinen & Hyönä, 2005). On the basis of Hyönä, Lorch, and Rinck (2003), we computed several eye movement measures as the number and the duration of the fixations made in each paragraph and also the number of regressions readers made from each paragraph to the initial paragraph of the texts. The eye tracking apparatus employed in the present investigation only allowed us to compute eye movement measures on a paragraph level. Even so, for the purposes of this study, paragraphs were the representation unit of interest, as they can provide information about intersentence coherence that are likely to have important influences on online processing of the relevant information of the texts (Hyönä et al., 2002) and also the possibility of examining systematic variations in processing between paragraphs.

Although there can be found a wide variety of research analysing the effects of relevance instructions on the processing of expository texts, to our knowledge, little has been studied combining online measures as eye tracking methods and offline measures as the quality of the recall from different expository texts. This can be understood as a methodological advance with respect to previous literature, as the combination of both kind of measures can be informative in order to have a better understanding about the reading processes and the subsequent product of the memory representation and also about the reading strategies elicited by different types of reading instructions. Moreover, it can be helpful in order to link the consistency between these reading processes and the patterns in the recall, as it is expected to be a correlate between the reading patterns and the information included in the summaries. Thereby, a reader using a selective reading strategy, dedicating more and longer fixations to question-relevant than to question-irrelevant text information, should be also expected to include more question-relevant than question-irrelevant information in the later recall task.

Purposeful reading can be described as a goal-directed activity in which readers interpret the signals of the context and the task to create their own mental representation, what will determine their reading goals and finally the kind of information they will extract from the text (Britt, Rouet, & Durik, 2017). Following the basis of the RESOLV framework proposed by the authors, we expected that readers who received specific relevance instructions should differentiate the question-relevant information in a more efficient way, being more selective in their processing. In this condition, the relevance signals given to the readers should elicit a more careful processing of the question-relevant text contents, which should be reflected in more and longer fixations on these regions, whereas the question-irrelevant paragraph should be more superficially processed. Besides, more regressions are expected to the introductory paragraph, which contains the question, from the question-relevant paragraphs, as possibly an attempt to build links between the question and the question-relevant information in the memory representation of the readers (Hyönä et al., 2003). As a consequence, this selective processing should be reflected in a better recall of question-relevant than question-irrelevant information, compared with the condition in which participants received general relevance instructions. There are no specific relevance signals that focus participants in this condition on question-relevant information, although the why question inserted within the text can also work as a more tenuous kind of relevance signal. Nonetheless, they are expected to distribute their attention more uniformly across the question-relevant and question-irrelevant paragraphs, and the content of both paragraphs should be represented in a more homogeneous way in their recall. In addition, we also interested in analysing how consistently readers who used the selective processing strategy used it along the six experimental texts.

Method

Participants

Participants were 41 students (16 men; age range: 20–23 years) enrolled at the Autonomous University of Madrid, Spain. All participants had volunteered to participate in the experiments, and they received extra course credit as compensation. All of them were native speakers of Spanish (the language studied here) and had normal or corrected-to-normal vision. Additionally, all participants who took part in this study were from the same academic group and the same academic year. All of them were third-year psychology students and participated in the same laboratory conditions.

All participants read the same six expository texts, but they were randomly divided into two groups according to the reading instructions they received: 22 participants received specific relevance instructions and 19 participants received general relevance instructions. The duration of the experiment was the same for both groups.

Apparatus

Eye movements were collected by an EyeTech™ Digital Systems VT2 infrared eye tracker, with two infrared light sources and an integrated infrared camera. The VT2 has two cameras mounted on a headband (one for each eye) including two infrared light-emitting diodes for illuminating each eye. The cameras sample pupil location and pupil size at the rate of 80 Hz. Registration was binocular, and for cases that it was not possible, registration was monocular. The camera was fixed under a 15-inch laptop computer on which stimuli were presented to each participant. Participants were also instructed to use a chin-and-forehead rest to stabilise their head positions during the test, positioned at about 60 cm from the eye tracker.

Materials

Eight expository texts were created for use as stimuli, and two were used only for practice. Each text was approximately 200–250 words long (Spanish version) and included different expository topics (Thames River pollution, Mediterranean diet, evolution of the suitcase, history of popcorn, urban growth, detective novel, insomnia and the greenhouse effect). All of these texts were divided into three paragraphs. Each text began with a short introduction that finished always with a why question about the main topic. Each topic was developed in two subsequent paragraphs: one included relevant information to the question and the other one involved filler information that was coherent with the topic but unrelated to the question (see Table 1). The answer to each question (relevant information) was introduced in the second or third paragraph; the order of presentation of the relevant and irrelevant paragraph was counterbalanced across participants. For each text, both paragraphs were equated in length in the original Spanish version. Each text fits on a single computer screen (maximum of 14 lines). Lines within a paragraph were typed single space; two blank lines were inserted between paragraphs. Each text was presented for as long as the participant cared to view it.

Procedure

The settings and the context in which the experiment was conducted were the same for all participants. The study was conducted in a small laboratory room, and each participant was run individually. The lighting conditions were the same for all the participants. For each participant, the eye tracker was calibrated using a 16-point calibration before the first practice text and then recalibrated after every two texts. Participants receiving general relevance instructions were told, ‘You will read a set of short expository passages. We want you to read the passages carefully, understanding as much of the passage as possible. Later, after reading, you will make an oral summary about main ideas to see how well you understood

Table 1. An example of one of the experimental texts.

The Thames River
For centuries, London has been exposing the Thames to high levels of contamination. In 1849 it was found that salmon, like the rest of the flora and fauna, had disappeared from the river. The water, though, was still used for human consumption, a fact which led to over 35,000 deaths from diphtheria epidemics between 1831 and 1866. **But how did the river become so contaminated?**
Because London was a large, heavily populated and industrialized city, the pollution dumped into the river was of a mixed nature. First, the Thames received huge amounts of untreated organic waste from the sewers of London. Second, industries produced chemical waste (such as hydrocarbons, synthetic detergents, phenols, cyanide) that changed the pH of the water. Both types of pollution completely extinguished any form of life in the river.
The contamination led Londoners to avoid the Thames in summer. Every viscous drop of water that passed carried the smell of two centuries of urban pollution. And beneath the surface, the river was dead. In more than 70 kilometers, the water contained almost no oxygen, and fish and other living creatures that inhabited the river had been eliminated long ago. Until the 80's, the Thames was one of the most polluted rivers in the world.

Note: The question and relevant paragraph are presented in boldface in the table but were presented without boldface in the experiment.

what you read'. Participants receiving the specific relevance instructions were told, 'You will read a set of short expository passages. We want you to read the passage carefully, focus on the question that appears at the end of the first paragraph, and understanding as much of the passage as possible to answer the question. Later, after reading, you will make an oral summary about the main ideas related to the question to see how well you understood what you read'. After participants indicated they had finished reading the relevance instructions, they read the two practice texts followed by the six experimental texts. After reading each text, participants completed an oral summary of the text according to their instructional condition. The text was not displayed during summarisation. Participants were allowed to read every text at their own pace. After each text, participants were asked to provide a summary of the text orally, and all the responses were recorded with a digital voice recorder. Every recording was manually transcribed after the experiment. When the summary was completed for the final text, the participant was debriefed and dismissed. The entire procedure was completed in approximately 25 minutes.

Measures and score

Three paragraph-level eye movement measures (see Hyönä et al., 2003) were computed for each of the six texts for every participant. The *number of fixations* (frequency) is the sum of all the fixations made in a paragraph. The total *number of regressions* reflects the number of times readers returned from each paragraph to the introductory paragraph that contains the question after the first reading of that paragraph. Regressions to the first paragraph are presumed to indicate checks by the reader of the relevance of a paragraph's content to the to-be-answered question (Wiley & Rayner, 2000). The *total fixation durations* (measured in seconds) refers to the sum of all fixation times for each paragraph.

Oral summaries instead of written summaries were selected for several reasons. First, an oral summary is different from a verbatim recall, as it is a concise statement of the most important information in a text, more spontaneous and natural than a written summary, while being more sensitive to the possible effects of type of instructions and to the use of selective processing (León & Escudero, 2015). Oral summaries could be also used concurrently with eye tracking measures. By contrast, written summaries are more elaborate because they require specific writing strategies (not only comprehension strategies), such as planning activities related to writing, introducing several possible re-elaborations, attention to grammatical correctness and the requirement of much more time to produce. A methodological limitation can be also controlled using the oral summary task, as it can be applied immediately after reading the text and it does not require recalibrating the eye tracking device more than necessary, avoiding to interrupt the timing of the experiments.

The summaries were scored for the number of words that contained ideas and corresponded in a coherent manner with the information presented in the introductory paragraph, the number of words that corresponded with the relevant paragraph and the number of words that corresponded with the irrelevant paragraph. Raters made a recount of the total number of words dedicated in the summaries to each paragraph. The criteria to decide which words corresponded to the information presented in one of the three paragraphs were the semantic relation of the contents of the oral summaries to the contents of the three paragraphs that conform the texts. One trained rater scored all summary protocols, and a second rater scored 30 randomly selected summary protocols. Both raters were unaware of the instructional condition to which a participant was assigned when scoring protocols. Interrater reliability was high (96%, Cohen's kappa = .83), so scores from the first rater were used in the analysis. Some examples of summaries generated by participants from both instruction condition groups are presented in Appendix B.

Results

Analyses of the eye movement data

The first set of analyses examined the results for the online measures to determine whether the type of relevance instruction affected how readers processed the relevant and irrelevant paragraphs during reading. Analyses of variance (ANOVAs) were conducted separately on the three eye movement measures. Each ANOVA had the same design. Relevance instructions (general and specific) was a between-Ss factor, whereas paragraph type (relevant and irrelevant) and the order of presentation of the relevant paragraph (located in second or third paragraph) were manipulated within-Ss. Table 2 shows means and standard deviations for each condition. Tables for the information about the models for all the dependent measures are presented in Appendix A.

First, consider the results for *number of fixations*. If the effect of specific relevance instructions is to induce participants to be more selective in their processing of relevant content compared with general relevance instructions, we would expect to see more fixations on the relevant paragraph than on the irrelevant paragraph in the specific relevance condition than in the general relevance condition. As Figure 1 illustrates, that is what was found. The interaction of paragraph type with instruction was significant, $F(1, 39) = 14.4$, MSE = 564.8; $p < .001$, $\eta^2 = .270$. As Figure 1 shows, there were many more fixations on the relevant paragraph than on the irrelevant paragraph when participants received specific relevance instructions, but there was no difference in the numbers of

Table 2. Dependent online (number of fixations, regressions and fixation duration) and offline (word count per paragraph) measures means and standard errors for each condition.

			Number of fixations		Number of regressions		Fixation duration		Word count	
Instruction	Paragraph	Order	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
General	Irrelevant	2nd P.	25.03	12.16	0.79	0.66	7.36	5.17	23.66	21.19
		3rd P.	29.37	12.28	0.53	0.59	8.38	3.64	22.49	22.69
	Relevant	2nd P.	26.75	12.70	0.45	0.70	7.73	4.09	46.17	23.74
		3rd P.	24.19	11.63	0.70	0.62	6.67	4.11	43.15	25.02
Specific	Irrelevant	2nd P.	19.85	13.96	0.48	0.36	5.85	4.92	2.09	7.72
		3rd P.	24.42	13.81	0.38	0.50	7.18	4.35	2.44	8.96
	Relevant	2nd P.	38.41	25.76	0.89	1.18	11.51	8.31	38.45	19.49
		3rd P.	35.04	23.05	0.90	0.64	10.00	7.39	40.25	21.93

fixations between the two paragraphs when participants received general relevance instructions. No other interactions were significant.

Second, we analysed *regressions* to the first paragraph that contains the question to see if the type of relevance instruction influenced processing associated with the question. Again, if specific relevance instructions caused readers to focus selectively on question-relevant information, we would predict more regressions from the relevant paragraph than from the irrelevant paragraph in the specific instructional condition but not in the general instructional condition. Figure 2 confirms that this is what was observed. Again, paragraph type interacted with instructions, $F(1, 39) = 6.51$, MSE = 1.44, $p = .015$, $\eta^2 = .143$. There were many more regressions from the relevant paragraph than from the irrelevant paragraph

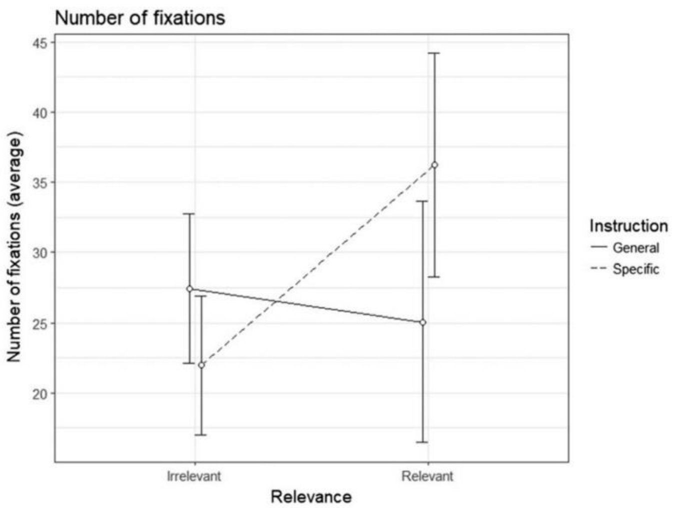

Figure 1. Number of fixations for the relevant and irrelevant paragraphs, as a function of instruction (general and specific). Error bars represent 95% CIs.

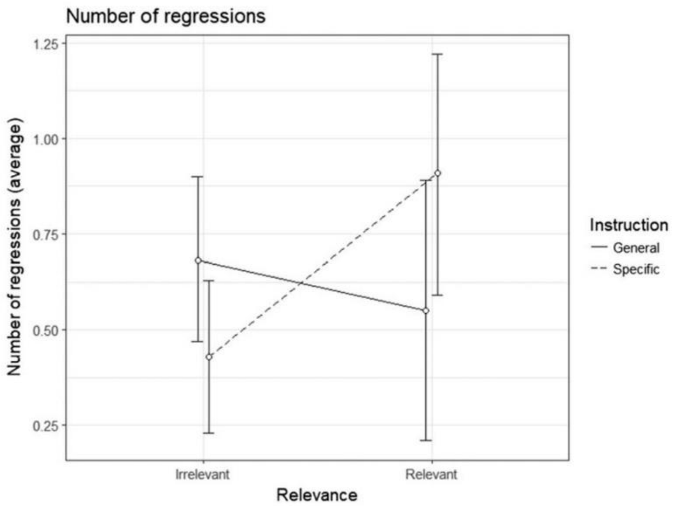

Figure 2. Number of regressions for the relevant and irrelevant paragraphs, as a function of instruction (general and specific). Error bars represent 95% CIs.

when readers were under specific relevance instructions, but there was no effect of paragraph relevance when readers were under general relevance instructions. No other interactions were reliable.

Third, consider the results for *fixation durations*. If the effect of specific relevance instructions is to induce participants to devote more time in processing relevant content compared with general relevance instructions, we would expect to see longer total durations of fixations on the relevant paragraph than on the irrelevant paragraph in the specific relevance condition. As Figure 3 illustrates, that is what was found. The interaction of paragraph type with instruction was significant, $F(1, 39) = 12.76$, MSE = 19.28; $p = .001$, $\eta^2 = .247$. As Figure 3 shows, fixation durations were longer on the relevant paragraph compared with the irrelevant paragraph when participants received specific relevance instructions, but no differences were found between fixation durations data for the two paragraph types when participants received general relevance instructions. No other interactions were significant.

In sum, the three measures of online processing were consistent in showing that participants receiving specific relevance instructions focused much more selectively on the content of the relevant paragraph than participants receiving general relevance instructions.

Analyses of the summaries

The oral summaries were scored for the number of words in each summary that were related to the introductory paragraph, the relevant paragraph and the irrelevant paragraph, respectively. These data were analysed using an ANOVA in which the between-Ss factor was type of instruction (general and specific) and the within-Ss factors were type of

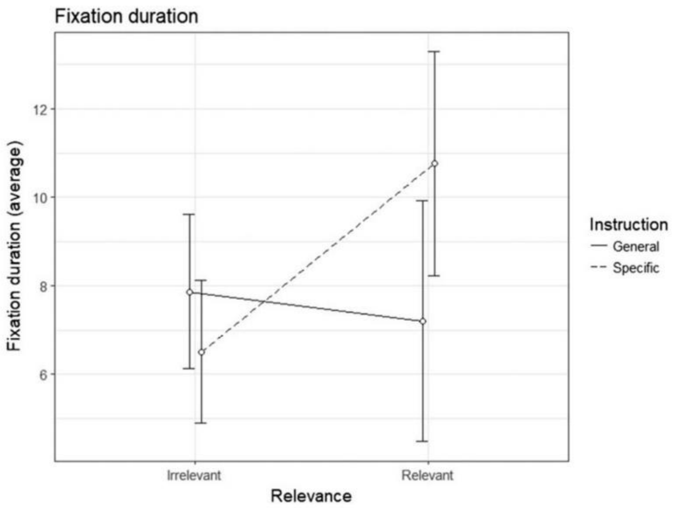

Figure 3. Fixation duration (in seconds) for the relevant and irrelevant paragraphs, as a function of instruction (general and specific). Error bars represent 95% CIs.

paragraph (relevant and irrelevant) and the order of presentation of the relevant paragraph (located in second or third paragraph).

The key finding is again that type of paragraph interacted with instructions, $F(1, 38) = 18.46$, MSE = 433.96, $p < .001$, $\eta^2 = .327$. As can be seen in Table 2, participants in both conditions recalled similar amounts of content from the relevant paragraph in their summaries; however, participants receiving specific relevance instructions recalled much less content from the irrelevant paragraph than participants receiving general relevance instructions. Again, readers in the specific relevance condition focused selectively on the content of the relevant paragraph as was appropriate to their instructions. Figure 4 and Table 3 show the average proportions of words recalled for each type of text paragraph (introductory, relevant and irrelevant) and the type of instruction (general and specific).

In addition, in order to analyse the consistency with which a reader applied a selective processing, we calculated the percentage of the words in their summaries originating from the relevant paragraph in each of the six texts. We classified processing of a text as selective if at least 80% of the words in the overall summary were recalled from the question-relevant paragraph. In the specific instruction condition, all of the readers consistently used a selective processing; specifically, 22.7% of the readers used a selective processing for five of the six texts and the great majority (77.3%) used a selective strategy for all the six texts. In the general instruction condition, the great majority of the readers used a selective processing for only two or fewer texts (i.e., 88.9%), and none of the readers used a selective processing for more than five of the texts.

Discussion

The purpose of the present study was to analyse how the type of relevance instruction affects readers' text processing, taking into account their eye movement patterns and the

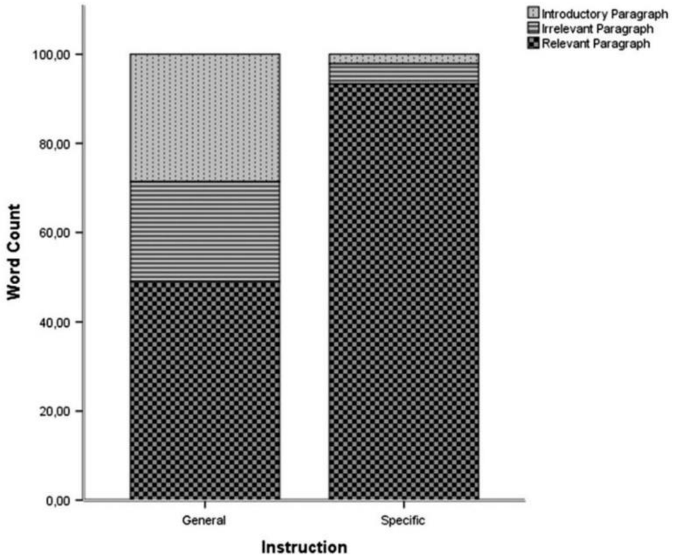

Figure 4. Mean proportion of words in oral summaries attributed to the introductory paragraph, the relevant paragraph and the irrelevant paragraph, respectively, as a function of instruction (general and specific).

quality of their recall. Although there is considerable evidence about relevance instructions affect processing and memory outcomes, little is known about how general and specific relevance instructions affects readers in terms of the goals they set and the strategies they implement in order to match their performance on the task demands. This study adds several points of interest to what we already know about the topic from most of the previous research. First, we investigated whether the type of relevance instruction influenced the selectivity of readers' processing strategies. Second, we looked at the nature of readers' processing strategies across six different expository texts to assess how consistent they were in their use of a particular strategy. About the methodological aspects, online measures (eye movements) and offline measures (oral summaries) were combined in the same study in order to triangulate different types of data that are informative to analyse selective text processing.

Our results demonstrate that general and specific relevance instructions exert pervasive influences on the encoding strategies that skilled adult readers employ during reading, promoting two distinct types of reading processes: a selective processing strategy and a

Table 3. Dependent offline measures (proportion account of words per paragraph, introductory, relevant and irrelevant) for each instruction condition (general and specific).

Instruction	% of words (introductory)	% of words (relevant)	% of words (irrelevant)
General	28.61	48.97	22.42
Specific	2.13	93.31	4.57

nonselective processing strategy. In the specific relevance instruction condition, readers activated a selective reading processing strategy in which they recognised the relevance of text segments early (i.e., relevant paragraphs), which then influenced how they allocated their fixations. Thus, they made more and longer fixations and more regressions and spent more time processing relevant segments than irrelevant segments. Moreover, readers in the specific relevance condition also recalled proportionately more content from the relevant paragraph in the oral summary task. In contrast, readers in the general relevance condition used a nonselective processing strategy, characterised by no additional time and no increase in frequency of fixations and regressions on processing relevant segments over irrelevant segments. When summarising, these readers recalled content equivalently across all paragraphs in the texts (i.e., they were not selective).

These data are consistent with most of the previous research about relevance instructions (e.g., Kaakinen et al., 2002, 2003; McCrudden & Schraw, 2007). Results of eye tracking studies of expository text comprehension show that readers spend more time processing perspective-relevant than perspective-irrelevant text information (e.g., Kaakinen et al., 2002). Also, these results complement results of eye-tracking research generated within the *perspective-driven text comprehension framework* (Kaakinen & Hyönä, 2008). According to this framework, specific relevance instructions led readers to adopt the question stated in the first paragraph of a text as the focus for subsequent text processing. This perspective caused activation of relevant concepts in the reader's knowledge base that, in turn, facilitated processing of related content in the text. The results are also compatible with models that propose differences in processing of relevant and irrelevant information based on *goal focusing* (McCrudden & Schraw, 2007), such as the adoption of *standards of relevance* (McCrudden et al., 2010) and the *focus assumption* (Graesser & Lehman, 2011). In general, these models predict that more attention will be devoted to relevant information within the question's receptive field than information outside of the receptive field, with the result that relevant information is more likely to be encoded (Kaakinen & Hyönä, 2008).

Given the evidence that readers were much more selective overall in their text processing when given specific relevance instructions than when given general relevance instructions, we were interested in how consistent readers were in their use of a selective processing strategy in the present experiment. The pattern we found is that readers in the specific relevance condition were consistent in their use of a selective strategy. All of the readers in the specific relevance condition were classified as using a selective processing strategy on either five (22.7%) or all six (77.3%) of the experimental texts. Even so, the specific context of the experimental task and the adaptation of the participant to the procedure may also have an influence on this effect, but we think this is still remarkable given the variety of topics across the texts and also the counterbalance of the order of presentation of question-relevant and question-irrelevant paragraphs. This effect also suggests that readers' adoption of a selective strategy may not depend on their familiarity with the text topic.

This study also showed the value of combining online and offline measures in examining how relevance instructions influence reading text comprehension processes in the same research. Combining online and offline data allowed us to explain why some readers spent more or less time reading irrelevant information and why they provided divergent summaries of the texts. By using online and offline measures, we were able to identify important differences in readers' goals and strategies that otherwise would have been hidden, such as in the results about their recall. For example, readers in the general relevance instruction condition used different reading strategies than readers in the specific relevant condition (selective vs nonselective reading processing), and they demonstrated different reading times, fixation frequencies and more regressions to the question of interest, as well as different recall patterns. Readers within each experimental condition described using different strategies to meet their reading goals, which was corroborated by online and offline measures. Readers with specific goals spent less time reading irrelevant information and remembered less of this information, whereas readers with general goals spent more time reading irrelevant information and remembered more of it. These findings suggest that the type of relevance instruction influences how readers enact strategies to meet their reading goals and how strategies influence memory. Combined, these data demonstrate empirically that relevance instructions affect intentions and reading goals, which affect processing of information that is more or less relevant to goal attainment, which also affects memory.

Limitations

The eye tracking apparatus employed in the present investigation only allowed us to compute eye movement measures on a paragraph level. Even so, as the results showed, we managed to obtain robust effects of the types of relevance instructions on text processing. Definitely, employing a more accurate eye tracking technology would permit to apply more precise analysis in order to evaluate the impact of relevance instructions on the eye movement patterns, having also more detailed information about what readers are actually doing while reading the relevant paragraph. Attending to that, we know that readers are spending more time reading the relevant paragraph than the irrelevant paragraph, but analysing the eye movements with a more precise technology would allow us to have more information about more specific causes related to this pattern. For instance, it could be related to more time invested on the relevant paragraph during the first pass reading, or it could be also due to a greater amount of re-readings on the relevant paragraph during the second pass reading. Nonetheless, analysing eye movements on a paragraph level as in the present study has proven to show significantly the beneficial effect of relevance instructions on learning, as was demonstrated in previous research (McCrudden et al., 2010; McCrudden & Schraw, 2007) that it is closely related to strategic processing of texts.

Educational applications and future research

These findings have important implications for educational practices. Assigning a comprehension perspective through relevance instructions should increase learning of perspective-relevant information from expository materials, such as textbooks (Lehman & Schraw, 2002). An important future direction is to examine how relevance instructions affect readers with differing abilities and different levels of experience reading expository texts. For example, future research could be conducted to investigate how younger students use relevance instructions and adjunct questions together. Good readers can adapt their reading strategies to the requirements of different tasks, but it takes experience to learn how to make appropriate strategic adjustments to specific reading goals and to adjunct questions. The case of relevance instructions might be a fruitful area for early instruction in strategic processing because domains can probably be identified for which the distinction between relevant and irrelevant content is relatively easy for young readers. Moreover, there can be also beneficial educational implications of applying relevance instructions in specific cases of individuals with reading comprehension difficulties. As it has been widely exposed in previous research, reading comprehension is a high-level task, which involves many different cognitive processes and skills (Cain & Oakhill, 2004). Difficulties in reading comprehension might be related to a large variety of causes, both of the text and of the context of the reading task and also of the personal cognitive processes and abilities, which finally lead to a loss of proficiency in the reading task. As the results of the present study are pointing, giving readers with comprehension difficulties clear instructions and relevance cues (e.g., McCrudden et al., 2010) about the reading task and specifically training them in the search for text relevance in early instructional stages (e.g., Britt et al., 2017) could be fruitful strategies in terms of helping these readers to develop clear and specific reading goals, which would finally lead them to be more focused and proficient in the reading tasks they are involved.

As was pointed earlier, future research should consider the application of relevance instructions to learning environments. Advancing research in this direction will require experimentation with a larger cross-section of participants, focused explorations of instructional prompts (i.e., those to instantiate different goals) to optimise learner comprehension and considerations of the alignment of purpose and relevance with a teacher's broader instructional plans. Along these lines, McCrudden et al. (2010) noted the importance of relevance instructions as a component of education's overall adherence to instructional alignment. These authors highlighted the need to align learning objectives, learning activities and measures of learning. The ability to distinguish relevant from irrelevant content in response to specific task instructions is an important instance of a competency that readers must develop in order to become efficient and effective as readers and learners.

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Appendix A. Information about the models for all the dependent measures

Table A1. Number of fixations

	F (*df*)	MSE	*p*	η^2
Between-Ss				
Intercept	181.93 (1, 39)	126,824.19	<.001	.82
Instruction	.56 (1, 39)	390.12	>.05	.01
Within-Ss				
Order	.34 (1, 39)	22.66	>.05	.01
Order×Instruction	.01 (1, 39)	.84	>.05	.00
Paragraph	8.96 (1, 39)	1,686.46	<.01	.19
Paragraph×Instruction	14.41 (1, 39)	2,712.83	<.001	.27
Order×Paragraph	3.24 (1, 39)	561.73	>.05	.08
Order×Paragraph×Instruction	.02 (1, 39)	2.81	>.05	.00

Table A2. Number of regressions

	F (*df*)	MSE	*p*	η^2
Between-Ss				
Intercept	66.71 (1, 39)	66.71	<.001	.64
Instruction	.10 (1, 39)	.09	>.05	.00
Within-Ss				
Order	.15 (1, 39)	.03	>.05	.00
Order×Instruction	.09 (1, 39)	.02	>.05	.00
Paragraph	3.16 (1, 39)	1.52	>.05	.08
Paragraph×Instruction	6.51 (1, 39)	3.12	<.05	.14
Order×Paragraph	3.26 (1, 39)	.98	>.05	.08
Order×Paragraph×Instruction	1.38 (1, 39)	.41	>.05	.03

Table A3. Fixation duration

	F (*df*)	MSE	*p*	η^2
Between-Ss				
Intercept	136.94 (1, 39)	10,660.96	<.001	.78
Instruction	.63 (1, 39)	49.24	>.05	.02
Within-Ss				
Order	.02 (1, 39)	.12	>.05	.00
Order×Instruction	.01 (1, 39)	.05	>.05	.00
Paragraph	6.77 (1, 39)	130.43	<.05	.15
Paragraph×Instruction	12.77 (1, 39)	246.09	<.001	.25
Order×Paragraph	3.24 (1, 39)	61.29	>.05	.08
Order×Paragraph×Instruction	.08 (1, 39)	1.50	>.05	.00

Table A4. Word count

	F (*df*)	MSE	*p*	η^2
Between-Ss				
Intercept	212.34 (1, 38)	116,691.03	<.001	.85
Instruction	11.94 (1, 38)	6,559.92	<.001	.24
Within-Ss				
Order	.18 (1, 38)	17.96	>.05	.01
Order×Instruction	.48 (1, 38)	47.39	>.05	.01
Paragraph	220.80 (1, 38)	31,940.00	<.001	.85
Paragraph×Instruction	18.46 (1, 38)	2,670.76	<.001	.33
Order×Paragraph	.77 (1, 38)	82.18	>.05	.02
Order×Paragraph×Instruction	1.18 (1, 38)	125.90	>.05	.03

Appendix B. Some examples of summaries generated by participants from both instruction condition groups (translated into English from the original Spanish versions, also included)

Specific relevance instruction

Dos tipos de contaminación produjeron la contaminación del Támesis: primero, la contaminación producida por los residuos orgánicos de las personas que vivían en Londres, ya que no había filtro, no se trataban debidamente e iban directos al río, y además, los residuos químicos que producían las fábricas de la época.

Two kinds of pollution became the river contamination: first, pollution produced by the organic waste of people who lived in London, because there were not any kind of filter, and that waste was not properly treated and was directly thrown to the river. Besides, chemical waste produced by factories of that period.

El Támesis se contaminó por dos razones: una por los residuos orgánicos que vertía la ciudad de Londres sobre él, ya que no existían sistemas de depuración, y otra los residuos químicos que vertían las fábricas y las industrias.

The Thames became contaminated because of two reasons: on the one hand for the organic waste that the city of London poured over the river, as there were no purification systems, and on the other hand due to the chemical waste poured by factories.

General relevance instruction

El texto habla del Támesis y de la gran contaminación que afectó Londres durante siglos. Fue a principios del S. XIX cuando se notó que había desaparecido mucho de la fauna y flora del río, porque estaba prácticamente contaminado por completo. Esto era porque al Támesis se vertían todos los residuos orgánicos que no tenían ningún tipo de tratamiento y también residuos tóxicos de las fábricas de la ciudad. Durante mucho tiempo, el río estuvo prácticamente muerto, no había apenas fauna y los ciudadanos tendían a evitarlo. El Támesis fue uno de los ríos más contaminados del mundo hasta los años 80.

The text is about the Thames and the great pollution which affected London during centuries. In the beginning of the XIX century, it was noticed that flora and fauna had disappeared, because the river was completely polluted. That was produced because both, all the organic waste, which was not treated in any way, and also the toxic waste from factories of the city, were poured to the river. For a long time, the river was practically dead, there were barely no fauna and citizens tended to avoid it. The Thames was one of the most polluted rivers in the world since the 80's years.

El Támesis ha sido uno de los ríos más contaminados. En 1849 se descubrió que todo el salmón que tenía había desaparecido a causa de la contaminación. Las causas de la contaminación básicamente eran dos: los residuos orgánicos que provenían de los desagües de Londres y una segunda que eran los componentes químicos que vertían las fábricas de Londres. Esto hacía que los ciudadanos no quisieran pasear por las orillas del río, porque olía mal y apenas había oxígeno, lo que provocaba que no hubiera ni fauna ni flora.

The Thames has been one of the most polluted rivers. In 1849, was discovered that all the salmon disappeared because of the pollution. The causes of the pollution were basically two: the organic waste that came from sewers of London and the chemical components that were poured by factories in London. That made citizens did not want to walk near the shores of the river, because of the bad smell and also because there was no oxygen, which produced the absence of fauna and flora.

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